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Optional Cost Models for Landfill Disposal of Municipal Solid Waste

Urban Systems Research and Engineering, Inc.
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OPTIONAL COST MODELS FOR LANDFILL DISPOSAL OF MUNICIPAL SOLID WASTE

by

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Contract No. 68-03-2868

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16. ABSTRACT

This report presents findings from an analysis of 45 landfills and associated transfer stations, balers, shredders, and transportation networks. The analysis of the sites attempted to determine how much it costs to build and operate a landfill and which factors have the greatest impacts on those costs. The studied landfills ranged in size from under 100 to over 5,000 tons per day and were located across the continental United States. A primary concern of the study was to determine the reduction in landfill cost from waste baling or shredding. The report presents the findings from the analysis, the implications of those findings and a methodology designed for use by local communities in determining their most cost-effective disposal system.

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FOREWORD

The Environmental Protection Agency was created because of increasing public and governmental concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment and the interplay between its components require a concentrated and integrated attack on the problem.

This report summarizes the findings from an analysis of 45 landfills and associated transfer stations, balers, shredders, and transportation networks. The sites were analyzed to determine how much it costs to build and operate a landfill and which factors have the greatest impacts on costs.

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Director
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ABSTRACT

This report presents findings from an analysis of 45 landfills and associated transfer stations, balers, shredders, and transportation networks. The analysis of the sites attempted to determine how much it costs to build and operate a landfill and which factors have the greatest effect on those costs. The studied landfills ranged in size from under 100 to over 5,000 tons per day and were located across the continental United States.

A primary concern of the study was to determine the reduction in landfill cost from waste baling or shredding. Analysis of the data indicates that any savings inurred at the landfill, because of prior baling or shredding, do not compensate for the added cost of the more sophisticated processing facilities. On the other hand, baling or shredding may be feasible in a situation where component costs for the entire landfilling system were exorbitantly high.

Another important finding is that landfilling is only a small portion of total costs. On average, both the haul and the processing components of the system are larger than the landfilling component. This report presents the findings from the analysis, the implications of those findings, and methodology designed for use by local communities in determining their most cost-effective disposal system.

The report was submitted in fulfillment of Contract No. 68-03-2868 by Urban Systems Research & Engineering, Inc. under sponsorship of the U.S. Environmental Protection Agency. This rport covers a period from September 1979 to November 1982 and work was completed as of November 1, 1982.

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SECTION 1

Recommendations & Conclusions

1.1 Introduction

Solid waste can be managed in several ways. Recycling can remove certain constituents, reducing volume. Incineration also reduces volume, and may recover energy. Baling increases density, and may lead to simpler disposal. Shredding may also simplify disposal. In the end, though, some portion of the waste will ususally be landfilled.

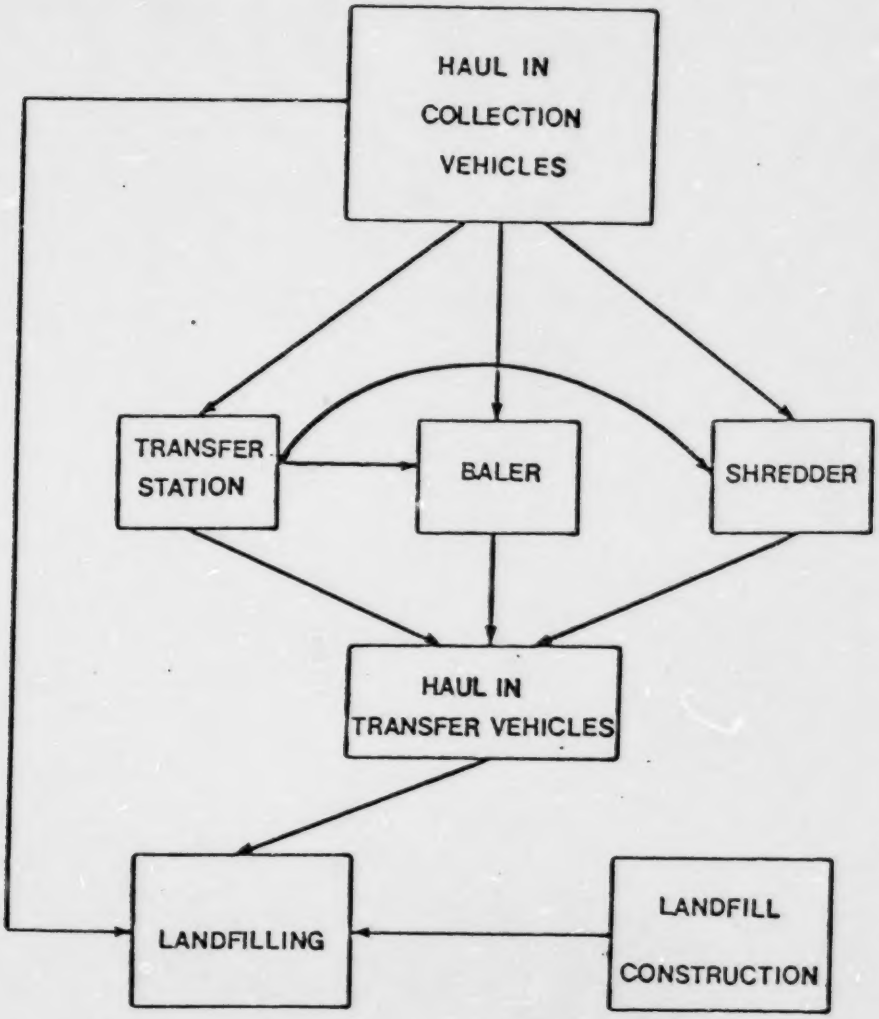
All steps in solid waste management cost money. An effective manager will try to find the system which acceptably handles the waste at minimum cost. But the number of options is large, and detailed engineering studies of every option would be much too expensive. Simple methods are needed to structure the various options and estimate rough costs for each step, so that extravagant options can be eliminated. The options which remain can then be analyzed in depth, and the best selected.

This report may help. Cost data were collected and analyzed from 45 operating Solid Waste Management Facilities (SWMF), and methods were developed to relate these findings to other local community information. The methods make it possible to compare the costs of systems with direct haul, transfer stations, balers, shredders, and various landfill locations and characteristics. Incinerators and systems with significant resource recovery were not included in this study.

Exhibit 1-1 shows the assumed structure for solid waste flows. Waste is generated along various collection routes and hauled in the collecton trucks to a processing facility, or a landfill. If the waste is processed, it is then transported in large vehicles to the landfill. Three types of processing were studied, Transfer, Baling, and Shredding. The landfilling costs depend on the types of processing as well as the landfill design (depth, number of lifts, etc.). Almost any site may be acceptable for a landfill given enough money for liners, leachate control, excavation, and other site-related costs. These landfill construction costs depend on site conditions, and are very different than the normal fill operations.

Exhibit 1-1

Solid Waste Management Components



This report describes the actual costs for each step, as found at the 45 SWMF visited. In addition, key factors affecting costs have been identified and analyzed and methods have been provided for cost estimation by communities.

Section 2 of the report presents examples of past research on the topic, and describes the research methodology in detail. Two key issues in the project were the allocation of costs among SWMF steps, and the identification of factors expected to influence each cost component. Section 2 describes decisions and assumptions.

A statistical analysis is, at best, only as good as its data. Section 3 describes site selection, data collection methods, and the results of data collection. It also presents descriptive material on the set of case study sites. Appendices A and B provide supporting material to Section 3 -- individual descriptions of each site, and the interview guide used for the data collection. Appendices C and D provide a Glossary of key terms and an index to the report.

Section 4 will be of interest primarily to readers concerned with modeling. It presents the statistical methods used, the modeling assumptions, and the results for each of the models. The results of various types of errors (e.g., in cost allocation) are discussed.

Finally, Section 5 provides our recommendations for using the results. It includes a step-by-step process, recommended data sources, analyses to test the results, suggested cutoffs for eliminating an option, and -- most important -- examples. Use of the approach may require a hand calculator, but other computer support is unnecessary. SWMF design is never easy, the designer will need common sense and a willingness to think to use the approach effectively. With this, some knowledge, and a calculator, first-cut cost analyses can be prepared quickly and easily.

1.2 Conclusion

The cost data collected from the 45 case study sites was analyzed using statistical methods. A series of cost curves also been developed which visually illustrate the influence of various parameters on the cost of various components. Exhibit 1-2 illustrates the relationship between the type of processing (transfer, baler, or shredder), the number of hours of operation per day, and cost per metric ton. Exhibit 1-3 illustrates the relationship between type of facility (conventional fill, balefill, or shredfill), tons per day processed, and cost per metric ton.

The principal findings of the study can be summarized as follows:

- The main variable affecting cost of haul in collection vehicles is the amount of time spent in haul on an average day.

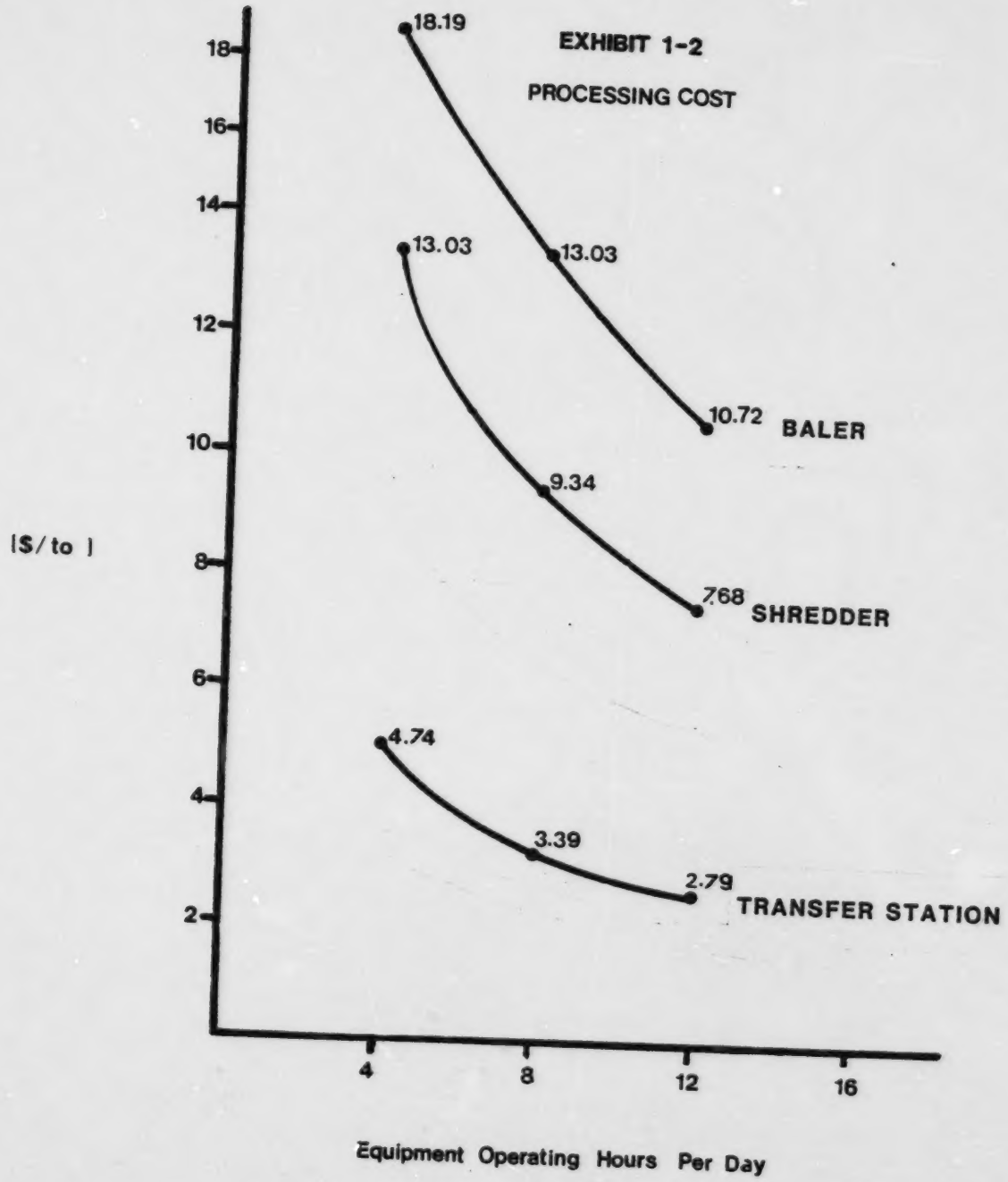
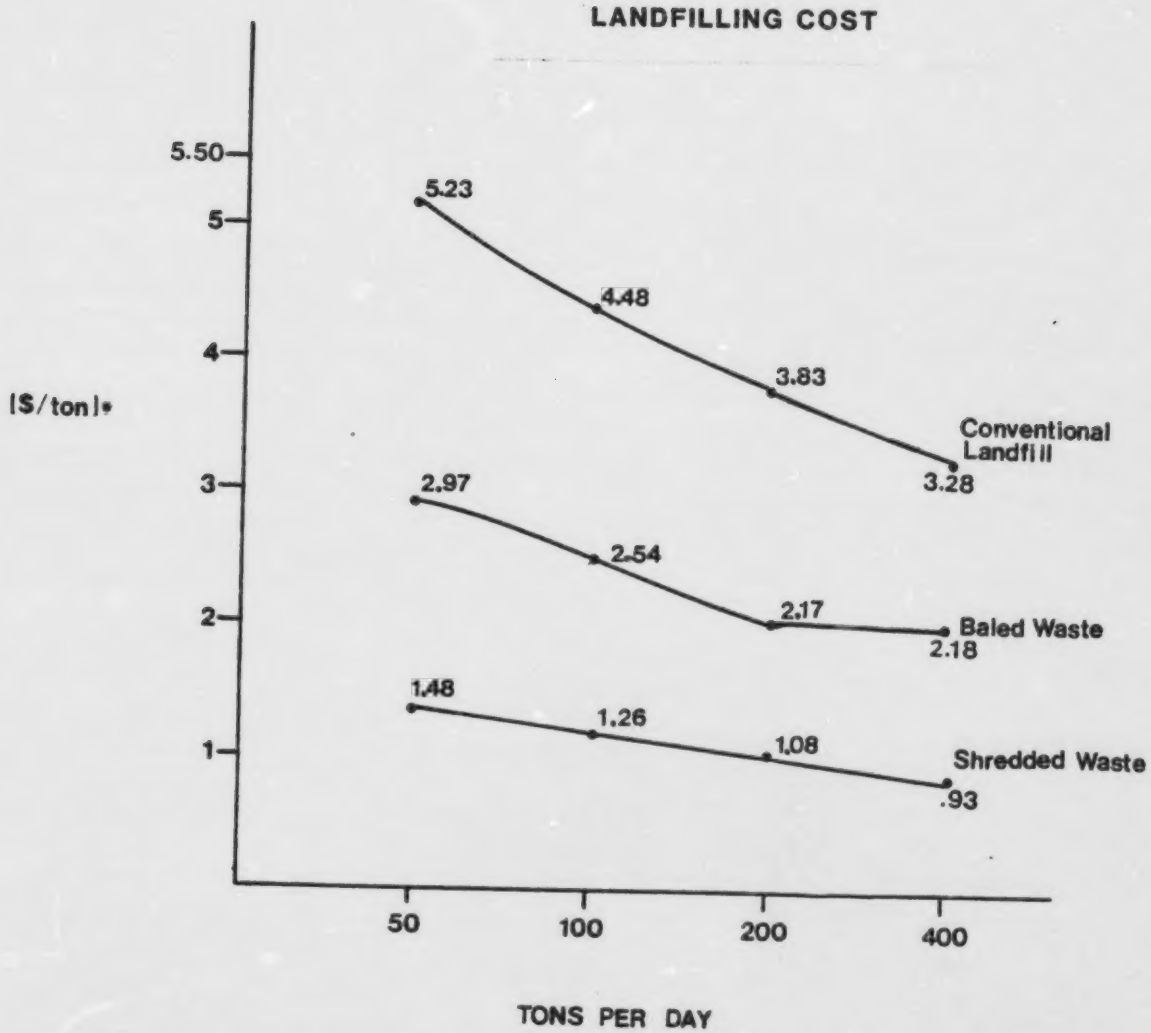


EXHIBIT 1-2
PROCESSING COST
18.19
13.03
13.03
10.72
BALER
9.34
7.68
SHREDDER
4.74
3.39
2.79
TRANSFER STATION
($/ton)
18
16
14
12
10
8
6
4
2
4
8
12
16
Equipment Operating Hours Per Day

EXHIBIT 1-3

LANDFILLING COST



*Does not include construction; phased construction and on-site cover assumed.

- For both haul in the collection vehicles and haul in the larger transfer vehicles, increasing vehicle capacity reduced costs. A 10 percent increase in vehicle size led to a 6-7 percent decrease in costs, across all sites.

- Baling and shredding had little effect on the cost of transportation in large vehicles. Distance, travel time, and total level of operations (tonnage) were much more important.

- Shredders and balers were, as expected, more expensive than transfer stations, both in capital and operating costs, correcting for other factors such as size. Further, the estimates for shredders is probably low. In general, the shredders were less clean, and apparently less well-maintained, than the other facilities. In addition, one shredder was not included in the models because it had been out of service for 325 days in the preceding year as a result of an explosion. To get a good estimate of shredder costs, it is necessary to look over a very long period. At the mean capacity (400 tpd) and 1 shift of actual operation, the model estimated costs of:

--baler	$13.03
--shredder	9.34
--transfer station	3.39

- Large processing facilities did not appear to be much, if any, cheaper per ton than small ones. However, the actual hours of equipment operation did have an effect on costs. Increasing the hours of equipment operation by 10 percent reduced costs by 6 percent. Increasing the hours by going from one to 1.5 shifts of equipment operation per day would reduce operating costs per ton by 30 percent. In essence, as long as there is waste to process, it makes the most sense to keep the equipment operating.

- With respect to landfilling, there were several key variables (see Exhibit 1-3). Increases in capacity reduced costs considerably with a 200 ton per day facility 27% less expensive per ton than a 50 ton per day facility. Baling and shredding also helped; a balefill was 43 percent less expensive per ton than a conventional landfill, while an uncovered shredded waste fill was 70 percent less expensive to run. Thus, the extra processing costs do lead to savings in landfilling. Note, though, that the shredded waste fills also seemed to operate under significantly lower standards, and these costs may underestimate new system costs. Two other factors were important: phasing of construction and the price paid for cover. All else being equal, having to

buy all cover off-site more than doubled the cost of landfilling. Phasing construction -- preparing the next area while filling the current one -- reduced landfilling costs, probably because it allowed more efficient use of equipment. However, this was not a particularly large or important variable.

- No model was developed for landfill construction costs. These costs varied greatly, and were influenced by a large number of site-specific characteristics. An engineering cost estimate for the site preparation phase is recommended as the best approach. This should include pollution control costs, of course.

Several variables showed no significant effect including:

- ownership (public/private)
- weather (amounts of rain and snow)
- shredder particle size
- bale size

As known, these factors can be important in specific situations. However, as measured at these sites, they seem to be generally less important than the variables discussed above.

Two of the sites deserve special mention, because of their costs. Both were small landfills in an eastern state with stringent groundwater protection regulations. Both required extensive liners, monitoring systems, clay cover, and other special treatment. They were the best examples in our sample of landfills which would meet stringent environmental requirements under RCRA. Our average cost for landfill construction at other sites in the 50-150 ton per day category was $1.34. These two sites had costs of about $14 per ton, though the landfilling costs once construction was completed were about the same as for other sites in that size range.

1.3 Recommendations for Further Research

The models proposed in the report can be used to provide preliminary cost estimates for any of these options and help direct engineering studies.

The results of this study confirm that high tech processing is expensive. This expense can only be justified if the use of processing eliminates considerable landfill construction costs or greatly increases inplace density, thus extending landfill costs. Since the first cost savings is not likely to be sufficient, the second may become the key factor in decision-making.

However, such analyses often require an estimate of inplace density, or the total amount of solid waste which can be disposed of per acre of landfill area. While there are many theoretical or experimental estimates of densities which can be achieved through compaction, baling or shredding, there is very little actual operational data on in-place densitites. None of the 45 sites in this study, which included most of the major balers and shredders, keep records of in-place density. Without operational data it is impossible to know how the theory translates into fact.

Thus, the collection of operational in-place density data, through surveys of landfills, could greatly improve the decision-making process.

SECTION 2

Theory and Past Research

2.1 Introduction

A transfer station is, in most cases, a building with a dumping floor, a pit, and some form of loading. Small trucks enter the station and dump their wastes into a pit. Larger trucks receive waste from the pit and leave when full. It is a fairly simple facility, at least in concept.

In reality, it is more complex because of varying operating conditions. Equipment is bought, used, fixed, and worn out. Staff are hired, promoted, and fired. Truck sizes change; so do work rules and procedures. A broken front-end loader might be replaced by a screw conveyor; a conveyor which does not work might be replaced by a loader. And there are many design options, including open air where the climate allows, plus converted incinerators or other facilities.

In trying to grasp the reality, several simplifying assumptions and several decisions have been made to allow consistent treatment from site to site.[1]

The first assumption is that Solid Waste Management can be divided into steps:

- Collection (ignored in this report),
- Haul in collection vehicles,
- Processing
  - Transfer,
  - Baling,
  - Shredding,
- Transport in Large Vehicles,
- Landfill Construction, and
- Landfill Operations.

These categories are described in section 2.3.

---

[1]Before describing these assumptions, it is important to see what others have accomplished, and with what results. Section 2.2 presents that review.

Similarly, cost components for each step are identified from the following basic list:

- o labor
- o facilities
- o stationary equipment (including buildings)
- o vehicular equipment
- o cover material
- o land
- o utilities
- o administration

Most of these categories have both capital and operating costs associated with them, as described in 2.4.

The various steps, and their costs, are influenced by decisions made by the manager (number of shifts per day, type of dozer); partially-controllable factors (prices, wage rates, distance to landfill); and uncontrollable factors (amount of waste, landfill site characteristics, required inches of cover). The factors that were hypothesized as being most significant are discussed in 2.5. Many did appear to be important, given the data and are part of the models in Section 4. Section 2.6 provides a summary.

2.2 The Literature on Solid Waste Management Costs and the Role of this Study

Almost every landfill or processing facility for solid waste management has had plans and designs prepared. Many of these include detailed cost estimates, used for calculating prices and feasibility. In some cases, alternatives are evaluated (e.g. whether to include a liner or not), and costs estimated for each alternative. These cost studies are dependent on the detailed local conditions, and are not generally applicable. (Examples include references 9, 22, 55)

This effort was designed to look at common factors and similarities in costs among sites. While individual cost studies (and actual costs) made up the data used here, previous reported studies are not comparable to this one. They will be more accurate for any particular application, but much more expensive for a wide range of options or sites.

Therefore, this review considers other studies which analyze a wide range of waste management alternatives. There are two types of interest:

- o Comparative cost studies, either similar to this one or using hypothetical costs; and

- o Regional modeling studies which evaluate the costs of many alternatives for a region or area.

The comparative cost studies are useful for an evaluation of our methods or assumptions in relation to the work of others; the regional modeling studies provide an alternative method for analyzing a wide range of options.

Comparative Cost Studies

There have been few public studies which have gathered actual costs for solid waste management in the U.S., and most of them have been performed for EPA. The study most directly comparable to this one was the Booz-Allen study for EPA in 1976.[1] This study analyzed costs for processing and landfill by collecting actual cost data from 30 locations. In many ways, it was a model for our work, and our assumptions follow their assumptions wherever feasible.

EPA has also funded some actual cost studies for various forms of processing, primarily incineration and resource recovery. These studies can supplement our work, and allow the evaluation to include those technologies as well. The Office of Solid Waste can provide guidance to these, many of which are summarized in (53).[2]

Besides these few studies, there is little research on actual costs. There are many reasons for this (as shown in section 3), primarily problems in identifying and allocating actual cost. As a result, most of the modeling studies and handbooks present costs developed for hypothetical sites. These may be checked with reality, and may be improved based on actual experience, but the starting point is a supposedly-typical situation. One or more parameters may be varied resulting in cost curves for use by planners and designers. Hypothetical cost studies are extremely useful -- they allow easy analysis of a wide range of prices and cost categories.[3] Assumptions can be clearly stated, and the effects of various assumptions analyzed. The only problem is that they may not reflect reality. To a certain degree, studies such as this one are useful for checking the results of the hypothetical cost studies. Typically, the design handbooks[4] present hypothetical site cost curves.

Regional Modeling Studies

The regional modeling studies are, typically, hypothetical cost studies directed at systems, rather than individual sites. The basic question for them is "What set of processing, transfer, and disposal sites will minimize total costs for this region, given the individual technology costs and generation points?" WRAP is the most commonly-used of these models, though there are many others.[5]

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[1]Booz-Allen & Hamilton, Inc. Cost Estimating Handbook for Transfer, Shredding, and Sanitary Landfilling of Solid Waste. EPA, 1976. Reference 7.

[2]See also 4, 35, 40, 41.

[3]References 6, 9, 10, 20, and 24 are examples of hypothetical cost studies

[4]References 1, 2, 3, 8, 21, 34, 37, and 49.

[5]See references 5, 11, 12, 15, 17, 26, 27, 28, 32, 33, 52, 54, 56.

These models greatly simplify the individual site costs, but are able to handle a very large number of alternatives, including perhaps 200 generation zones, 20 possible processing or transfer sites, 5 technologies, and 20 landfill sites. Given that level of analysis, they only use the simplest cost formulas: processing at a site, for example, might be assumed to cost $200,000 per year plus $15/ton.

Where the number of potential sites is large, and the number of alternatives may be in the millions, these models are extremely useful. They may be the only reasonable choice for a decision-maker, and will allow many of the options to be eliminated, so that detailed design is required for only a few.

If a community has only one option, no model is required: they should proceed directly to detailed design for that system. If a community has many options, the regional models should be used to reduce the set of alternatives down to a reasonable number. Our approach covers the in-between situation, where a community may have 2 or 3 possible sites, and a few technologies. It allows analysis of all the options in a few days, using a hand calculator, and without the investment required by a regional computerized model. It provides better cost estimates than the regional models, and (we believe) than the hypothetical studies and handbooks, though not as good as site-specific analyses.

Therefore, the approach presented in Section 5 fills a gap in the literature, between the complex regional models and the individual site studies. A small investment of time and effort by a community or engineer using this approach may limit the range of options down to a few worth detailed design, allowing better choices to be made at low cost. If this approach does not fit your needs, the references provide citations for excellent work which present the other options for cost analysis.

2.3 Steps in Solid Waste Management

Exhibit 1-1 showed the basic steps assumed to be part of solid waste management. Exhibit 2-1 shows some of the components in more detail. Most of these are straightforward, as described below.

Collection costs were not included in this study. See references 29, and 53 for a review of cost studies and methods for reducing collection costs.

Haul costs include all costs for vehicles and crews from leaving the collection site to return, including a portion of breaks and downtime. Dumping time at landfills or processing facilities is included as part of haul.

Processing includes all costs allocated to the processing facility, from staff time for weighing and dumping through loading of the outgoing vehicle. Equipment costs for purchase, maintenance, and operation are all included in processing.

Exhibit 2-1

Steps in Solid Waste Management

HAUL: in packer trucks from collection area

1. Haul
2. Dumping -- includes queueing time, etc., costs of vehicle and occupants
3. Return to collection area

PROCESSING: (similar for shred, bale, or transfer)

1. Entry (processing system receiving costs)
2. Storage
3. Conveyance
4. Processing
5. Conveyance
6. Storage
7. Loading

TRANSPORT: (large vehicles between or within sites)

1. Haul
2. Dumping (vehicle related costs)
3. Return

LANDFILL CONSTRUCTION:

1. Acquisition
2. Design
3. Access
4. Facilities Construction (buildings, primarily)
5. Pollution Control (fences, lagoons, drainage, monitoring)
6. Excavation
7. Post-Disposal costs (final cover, revegetation)
8. Deacquisition

LANDFILLING:

1. Entry (site related costs)
2. Cell construction
   --install waste
   --compact
   --cover
3. Daily cover and compaction
4. Site maintenance (litter, roads, vectors)

Transport costs are similar to haul, but for larger vehicles (either off-road within a combined processing/landfill site, or between processing and landfill. Transport may also be between a transfer station and a processing site or landfill. Note that vehicle maintenance costs would go here even if, for example, the landfill had ruts caused by poor operation which led to increased vehicle maintenance.

Landfill Construction and Landfilling: These cost categories are not usually kept distinct in the literature, but we found the distinction to be important. Site preparation and work proceeds essentially independently from the actual day-to-day operation of the landfill itself--and, in fact, is more closely related to site characteristics and engineering than to how the waste is buried. Landfills are composed of land to which certain construction improvements are made (site-related costs), and landfilling, which could be performed in a similar manner on almost any piece of suitably-improved property. This provides a way to handle problems shown in the Booz-Allen framework with cover material costs, environmental controls, liners, and other site-specific parts of the overall system.

Note that the distinction is not one of capital vs. operating. Compaction vehicles or bulldozers are capital expenses for the landfilling component; wastewater treatment plant operations and maintenance and movement of fencing would be operating expenses for the site development component.

In most of our sites, site preparation was done in conjunction with landfill operations. Usually, the equipment was used for site improvements whenever the load was light, and extra time was available. As discussed in Section 3, though, it is possible to estimate the time allocated to site preparation. As a result, the landfill operations models in Section 4 worked well, while the models showed landfill construction to be site-specific, as expected. The distinction was crucial to the success of the work, and should be continued in future research.

2.4 Cost Categories

After much analysis of fixed and variable costs, long-term intermediate-term, and short-term costs, and various other breakdowns, splitting costs into "capital" and "operating" best fit the needs of the project. Whatever division is used, it is necessary to include all costs in the scheme. Use of capital and operating costs allowed the most direct comparability with the Booz-Allen results. The various subdivisions of costs were also chosen to replicate the Booz-Allen analysis as closely as possible. These subdivisions, which are shown in Exhibit 2-2, are similar to the Booz-Allen categories.

Exhibit 2-2

Cost Categories

CAPITAL COSTS:

A. Land

B. Site Construction

--design and architecture
--site preparation
--demolition
--grading
--construction
--other

C. Stationary Equipment

--scales
--compactors
--conveyors
--pushpits
--shredders
--leachate treatment
--other

D. Vehicular Equipment

--packer trucks
--transfer trucks
--trailers
--draglines
--dozers and loaders
--other

OPERATING COSTS:

A. Labor

--salary and wages
--fringes
--other

B. Stationary Equipment

--maintenance and repair
--power
--other

C. Vehicular Equipment

--maintenance and repair
--rental
--fuel
--other

D. Facilities and Site Management

E. Utilities

F. Administrative

G. Cover Purchase

H. Other

2.5 Model Specification

Fifteen models were developed for the project, based on the steps and cost categories. Models were developed for capital costs, operating costs, and total costs for each of

- Haul,
- Processing (transfer, shredding, and baling)
- Transport,
- Landfill Operation, and
- Landfill Construction.

For each model, a set of variables was selected (see Exhibit 2-3). These variables were likely to be significant determinants of costs. All models were expressed in costs per metric ton, for simplicity and usefulness (though other forms were tested, as shown in section 4).

In the analysis, there were expected to be a number of direct interactions among the system equations (e.g. existence of baling affects both baling cost and also landfilling cost). This led to some interaction in the error terms, particuarly where costs must be allocated--with some measurement error--to the different submodels. If most errors had arisen in cost allocation--either at the site or in our analysis--then a total cost model would have been best. However, it appeared that most errors arose from misspecification of the model equations or related problems, so it was best to work with the component models.

A related modeling issue was whether to use actual or standardized prices, depreciation schedules, and accounting rules. To the extent that the operators reduce costs, they do so in response to real prices. Standardized prices are inconsistent with their decisions. On the other hand, standardization did reduce some sources of variation, leading to better models of the effects of the independent variables by reducing exogenous minor effects.

The "next site" issue--whether to include replacement costs for the site in analysis of landfill policies--does not enter into these models directly. However, it does enter into applications of them, since it can influence operating policies. Section 5 covers this issue.

2.6 Summary

This section briefly presented the conceptual work behind the data collection and models. Section 2.1 described some of the existing approches, and where the techniques presented in section 5 fit -- in other words, how best to use our results. Sections 2.2 and 2.3 identified the steps in solid waste management and showed how costs were divided up for those steps. In section 2.4, the factors were presented which affect costs for each of those cost categories.

Exhibit 2-3

Major Hypothesized Independent Variables

Model 1 Capital cost, Haul

Independent variables and data:

Capital cost of packer trucks (or truck rental), haul time (including dumping and return), total daily use time.

Ideally, capital cost are the cost of the portion of the truck's time spent in haul.

Model 2 Operating Cost, Haul

Similar to capital costs, except that per mile fuel and maintenance costs and per hour labor costs (and crew size) are used as cost coefficients. The goal is to get the average cost of the time and mileage spent in haul.

Model 3 Total costs, Haul

Sum of operating and annualized capital.

Model 4 Capital cost, Transport

Assuming the vehicles are dedicated, this is the cost of all transfer trailers and any tractors used with them.

Using the precepts of queueing theory, it should be possible todevelop relation filling, dump, and haul time (and daily load) to the number of vehicles required. This could be the basis for the forecasting model.

Model 5 Operating Cost, Transport

Wage rates and per-ton mile fuel and maintenance costs; travel time and distance between sites; queueing time at each end.

Model 6 Total Costs, Transport

Sum of annualized capital and operating.

Model 7 Processing Capital

Scale is the major factor affecting costs, though sidestream separation or other processing will add unit processes. For data collection, a full materials flow diagram is useful. Because scale, climate and proximity to residential uses may be critical, along with the usual prices for labor and materials.

For balers, the models are similar to transfer, though the output density of the baled waste is expected to be correlated with baler cost. Input weight characteristics are useful control variables. Shredders are also similar.

Model 8 Processing Operating

Again, scale is the most significant factor, though we may wish to look both at capacity and actual operational use. Density of the incoming waste might have some effect, but probably small. Data on the detailed operating procedures would be valuable, and may lead to some useful variables being developed later.

Baler operating will be similar to transfer operating. DIfferent unit processes will be used (e.g. forklift loading instead of dozer), but the key concerns should be the same, and those are operating policies, scale, and waste characteristics. Maintenance costs may be correlated with brand name or model, however.

Similar to transfer and baler, though maintenance may be more of a concern, and may have implications for required storage and the like. A variable measuring mean time between failures or downtime would be useful.

Thus, the processing model needed data on total capacity, and used capacity, input and output waste characteristics, and operating policies along with materials flow diagrams for the operations, and data (where available) be significant. For climate, days below freezing and average relative humidity were likely factors.

Model 9 Processing Total

Sum of annualized capital cost and operating cost.

Model 10 Landfilling Capital

Capital costs should be related to the size of the landfill, the type of waste landfilled (e.g. baled vs. packer truck), the incoming density of the waste, the climate (muddy or not) the avaiability of cover on-site, and operating policies for the fill. In addition, the density in the fill should be correlated with capital costs for equipment.

Model 11 Landfilling Operations

The same variabales appear to apply as for landfilling capital.

Model 12 Landfilling Total

Sum of annualized capital and operating costs.

Model 13 Landfill Construction Capital

The major factors here will be the amount ofland and competing uses for it, its characteristics (wetland, high groundwater, etc.), the total design capacity of the fill, and state regulations.

Model 14 Landfill Constructin Operation

The major factor here will be what types of operations are required at the particular site. This should be the focus of data collection in this category.

Model 15 Landfill Construction Total

Summ of annualized capital cost and operating cost.

SECTION 3

Data Collection

3.1 Introduction

There are many potential pitfalls in any data collection effort. For example, the sample from which data is collected may not accurately represent the population being studied. The data may be inaccurate or may not be useful in answering the questions the study is supposed to address. Every precaution was taken to avoid these and many other potential data collection problems.

For this study a sample of 45 solid waste management facilities was selected. The objective was to gather information about these operating facilities to determine which factors most influenced the capital and operational costs. Thus the design of the data collection effort involved two important phases: site selection and data collection methodology.

The Environmental Protection Agency's Municipal Environmental Reseach Laboratory, which commissioned this study, specifically required that cost be standardized in three ways:

- correct all costs for inflation to a base year,
- use uniform labor and overhead rates, and
- discount all capital plant and equipment by the same method.

By standardizing costs in this way, the project designers hoped to reduce the number of variables, and thereby more clearly highlight the impact of the remaining design and operational factors on costs.

Correcting for inflation greatly aids the multi-site analysis, since the relationship of costs within the case are constant and the comparison across cases is much more realistic. The same argument holds for labor costs and discounting method. However, there are two weaknesses in this argument which must be kept in mind when reviewing the results of this study. First there is an implicit assumption that the actual cost of labor and discounting methods have little or no impact on alternative selection; second, that using these rates does not seriously alter the relative costs of labor and materials. Before developing the model, the data were examined to evaluate the impact of the standardization. The results of this analysis indicate that the impacts are minimal and are clearly outweighed by the advantages.

3.2 Selection of Case Study Solid Waste Management Facilities

Strategy

The contract called for the collection of data from nine sites for each of the following five solid waste management schemes, for a total of 45 sites:

- Direct Haul Systems,
- Transfer stations,
- Balers - Untied,
- Balers - Tied, and
- Shredders.

To meet the overall objectives of the project, a set of criteria was developed for the selection of solid waste management facilities to be used in the data base:

- The waste form the processing facility had to be landfilled (Minimal ferrous recovery was acceptable)
- Records of the weights of waste processed had to be available,
- The facility had been in operation for at least one year prior to January 1980, and
- Parties at the site had to be willing to participate in the study.

Having established these minimum criteria, a networking process was initiated to identify potential sites. The networking process involved contacting persons knowledgeable in the field in conjunction with an extensive literature review. Listed below are the major sources used:

- Waste Age "Shredder and Baler Index", July 1979
- EPA Regional Offices
- State Solid Waste Offices
- John Thompson, EPA Office of Solid Waste
- Allen Geswein, EPA Office of Solid Waste
- Dr. Barbara J. Stevens, President of Ecodata, Inc.
- Bonnie Ritterhouse, EPA
- Shredder, Baler and Transfer Station equipment manufactures

After a potential site was identified, the local officials were contacted to verify site characteristics and data availability. Many potential sites were elimiated due to the lack of scales.

The Waste Age "1979 Shredder and Baler Index" identified 59 shredders and 25 balers. Our interviews with various experts in the field indicated that this list was complete. Since the objective of this study was to determine the impact of various processing proceedures on landfilling costs, only facilities which shred or bale primarily for landfills were considered. After eliminating all facilities with significant resource recovery, RDF, or incineration components, the list was reduced to 27 shredders and 15 balers.

After eliminating all sites which did not have records of the weights of waste processed, the final list of candidate sites included two tied balers, seven untied balers and 14 shredders.

Because of the limited number of acceptable sites, a new selection strategy was devised. First, all the balers were grouped together. Second, every effort was made to include all of the acceptable shredder and baler facilities. Finally, selection of transfer stations and direct haul facilities was made to insure a reasonable sample distribution of the following parameters:

- size, with an effort to focus on smaller facilities,
- ownership, with inclusion of private, and public facilities, and
- geographical location, while permitting reasonable logistics for field work.

Sites Selected

The final sample included 12 balefills, 9 shredfills, 11 transfer stations and 13 direct haul systems, for a total of 45 sites. In this section the general characteristics of the facilities selected will be discussed. For more detailed information, the individual site summaries in Appendix A should be consulted.

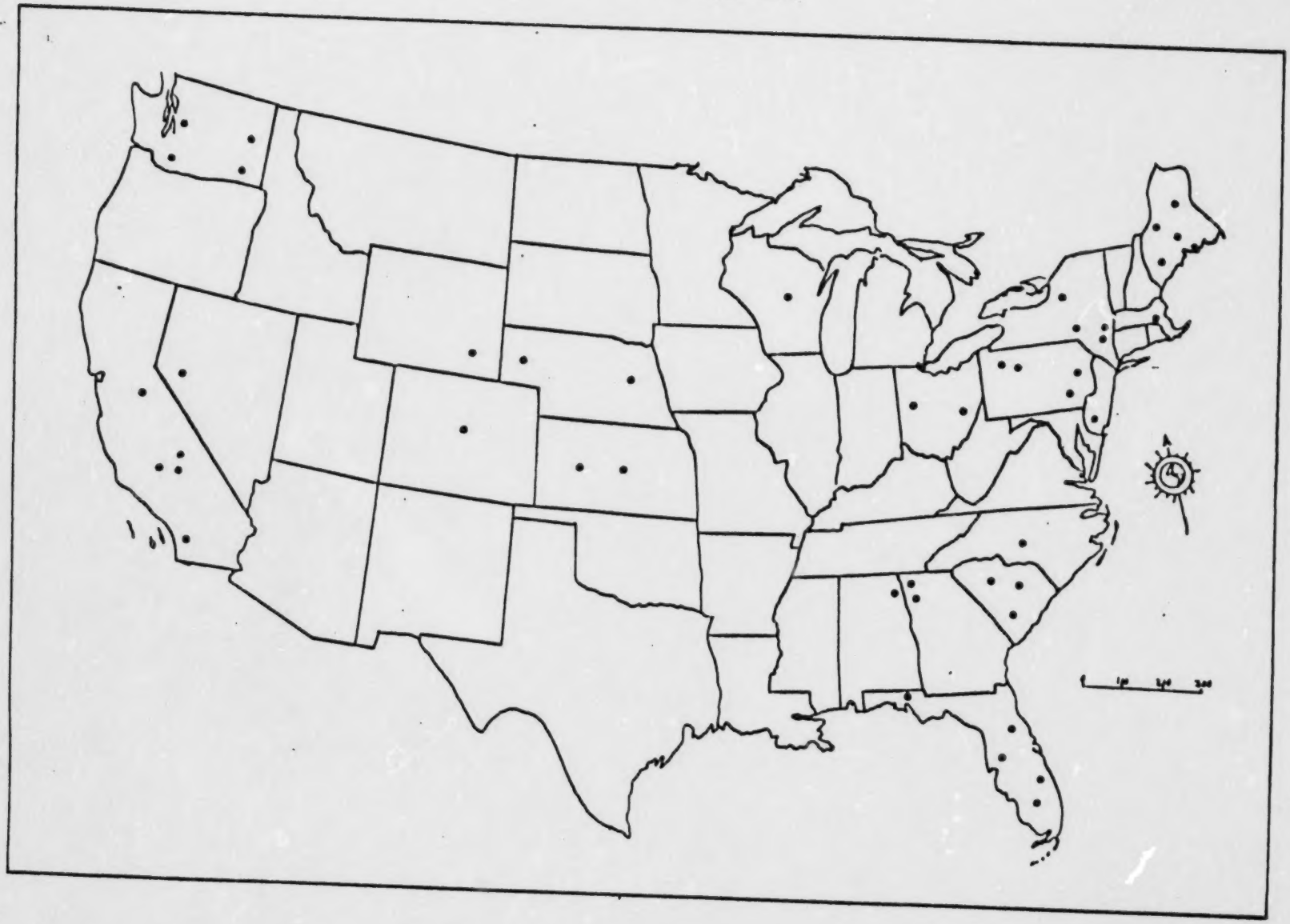
Researchers visited all of the balers and shredders which met the minimum criteria for inclusion in the study. Therefore, the geographical or size distribution of these sites were not controlled. Exhibit 3-1 shows the locations of the sites visited. Exhibit 3-2 shows the distribution of facilities by type and size. Exhibit 3-3 displays the distribution of facilities by type and EPA region. Exhibit 3-4 compares size and location. Exhibit 3-5 presents the names of non-confidential sites.

All of the shredders are located in the eastern part of the country and are generally large installations. Similarly, transfer stations which have scales tend to be in the larger size categories. The sample has a more even distribution by size for balers and direct haul systems.

Of the 45 sites visited, 18 had some form of leachate collection and another 16 plan leachate facilities in the future. Of the 18 sites with leachate collection, seven discharge leachate to a sewer, four recycle leachate over the fill, and seven have on site leachate treatment.

Over half of the sites visited have some sort of liner. Eighteen sites use natural clay liners while five sites utilize some form of man-made liner.

Exhibit 3-1



LOCATION OF THE 45 CASE STUDY SITES

Exhibit 3-2

Number of Sites by Size and Type

Type / Design Capacity Metric Tons	0-100	100-300	300-600	600+	Total
Haul	4	3	2	4	13
Transfer	1	1	6	3	11
Shredder	-	3	2	4	9
Baler	3	3	4	2	12
Total	8	10	14	13	45

Exhibit 3-3

Number of Sites by EPA Region and Type

EPA Region / Type	1	2	3	4	5	6	7	8	9	10	
Haul	1	1	1	2	1	-	2	-	4	1	13
Transfer	2	-	2	3	-	-	-	1	2	1	11
Shredder	1	1	1	4	2	-	-	-	-	-	9
Baler	1	2	-	3	1	-	2	1	-	2	12
Total	5	4	4	12	4	-	4	2	6	4	45

Exhibit 3-4

Number of Sites by Region and Size

Design Capacity Metric Tons / EPA Region	1	2	3	4	5	6	7	8	9	10	Total
0-100	2		1		1		2	1		1	8
100-300	3			4					1	2	10
300-600		2	1	5	2		2	1		1	14
600+		3	2	3					5		13
TOTAL	5	5	4	12	3	0	4	2	6	4	45

Exhibit 3-5

Names of Non-Confidential States

Direct Haul to Landfill	Shredder Processing	Baler Processing	Transfer Station
Ft. Lauderdale, FL	Onondoga County NY	Portland, ME	Hamden, ME
Grunderville Landfill, Warren, PA	Guilford County	Atlanta, GA	New Gloucester, ME
Spadra Landfill, Los Angeles County, CA	Appleton, WI	Pullman, WA	Columbia, SC
Miramar Landfill, San Diego, CA	New Castle, DE	Oyster Bay, NY	Mission Canyon Landfill, Los Angeles County, CA
Carson City, NV		Smithtown, NY	Sacremento, CA
Marion, MA			Pensecola, FL
Shawnee County, NJ			Lycoming County, PA

3.3 Data Collection

A considerable amount of data was collected from each of the solid waste management systems visited. There were three basic categories of data: background, operational and cost. The data were gathered during a series of pre-visit telephone interviews, a site visit, a review of documents, and follow up telephone calls. A detailed interview guide was developed to insure that the correct questions were asked and to provide a mechanism for organizing the information collected.

Background Data

Before cost data could be gathered, it was necessary to identify what parties actually incured costs for the various components of the solid waste management systems. The Pre-Interview Organizational Profile questionaire was developed for use during the pre-visit telephone interviews, to determine which parties where responsible for which components. USR&E staff then determined which parties should be contacted during the data gathering processes and scheduled the site visits accordingly.

The sample included a wide range of possible administrative forms. Counties operating facilities used by adjoining cities, cities operating facilities used by counties, public agencies leasing facilities from private firms, and private firms contracting to operate publicly owned facilities were all present. In many regional systems, the haul component was performed by a large number of both public and private haulers. A careful analysis was required to insure that the costs facing the various parties were allocated properly to the system components as defined for this study.

Operational Data

The objective of this study was to develop cost models which would describe the impact of various operational factors on the cost of operating a solid waste management system which ultimately relies on landfilling. To meet this objective USR&E hypothesized which operational factors would be most likely to affect cost, and collected information on these factors for later inclusion in the models.

For all components, data were collected on the size of the operation based on weights of waste processed. This information was critical since the model was to be developed in terms of costs per ton of waste processed.

Haul operational data focused on the factors which influenced the resources dedicated to hauling wastes in collection vehicles from the final pick-up point to the discharge point. The resources invested include labor time, equipment time, and fuel. Data were collected on the percent of the work day dedicated to hauling rather than collection, the distance of the haul, average tons per load, and the crew size.

Processing operational data was meant to reflect the efficiency with which the facilities are used. Data were collected on the design capacity, the actually wastes processed, days lost to down time, hours of operation per day, and days per year. Availability of storage capacity for both processed and unprocessed waste was determined. For transfer facilities it was noted whether the wastes were compacted or not. For shredders, the average particle size and the existence of metal separation were noted. For balers the type of facility, either tied or untied, and the size and weight of the bales was recorded.

Transfer in Large Vehicles operational data focused on the resources used in transporting processed wastes to the landfill face. Data gathered included vehicle type and capacity, crew size, transfer distance, and round trip time.

Landfill Operations factors which might influence cost, other than size, included the number of types of waste streams handled, age of the facility, method used, number and height of lifts, amount of daily cover, and source of cover.

Landfill Construction data included type of liner, if any, type of leachate collection and treatment if any, and landfill method used. An important factor also was whether the landfill construction was phased with operations, or whether the fill was constructed all at one time.

Cost Data

There are both capital and operational costs for each component of each solid waste mangement system studied. While it was often difficult to segregate the costs, this exercise insured that the costs were comparable from site to site. This was essential before the data could be used as the basis for the models.

As discussed earlier, the RFP required that the costs be standardized for labor rates, inflation and discounting method. As a result it was not enough to simply take a line item out of an annual budget. Labor and capital portions of each cost had to be calculated.

Labor hours, both straight time and over-time, were determined. From this information a standardized labor cost was calculated which could then be incorporated in the operational cost for each component.

For all capital equipment the initial price and date of purchase or construction was determined during the inteviewing process. Then all costs were corrected for inflation using the ENR Construction Cost index to a common date of June 1979. Finally, when determining the annual capital costs, all plant and equipment were discounted according the the following standards set forth in the contract; this also followed IRS schedules.

o Vehicles	5 years
o Stationary equipment	10 years
o Buildings	20 years
o Land	no discounting or appreciation

Data Collection Methodolgy

The interview guide was first developed in draft form and reviewed by EPA. A pretest of the guide and interviewer training were then conducted. Based on the experience of this pretest, the final interview guide and organizational profile were developed.

Efficient one and two week field trips were then planned, and the staff assignments made. Each staff member scheduled his or her own trip, conducting previsit interviews at the same time.

Each site visit included a tour of the facilities, and a general discussion of the operations. Detailed cost and operational questions were directed to the appropriate person. Documentation, including annual reports, research reports, and annual budgets were requested.

After returning to the office each staff member calculated the standardized costs and coded the results for inclusion in the computerized data base. All calculations were checked by other staff members.

3.4 Findings

Considerable data were collected from each of the 45 sites included in the study. In some instances it was not possible to gather complete information on one or more components of the solid waste management system. The most typical example would be a regional transfer station which accepted waste from a large number of public and private haulers. For this type of system specific cost data was not collected for the haul component.

The findings of the study fall into two broad chategories. Operational factors which are discriptive and often influence costs and Total Costs which include capital and operations costs. Exhibit 3-6 presents the average, minimum and maximum values for the key operational factors. Taken independently these factors provide only a picture of the sample. However, these operational factors provided important input as independent variables to the modeling process which is discribed in more detail in Section 4.

An attempt was made to select sites which would meet their states criteria for acceptable landfill facilities. It was not possible to always meet this criteria because of the limited number of sites available. While most of the sites visited did not have liners of any kind, 15 did have natural clay liners and four had manmade liners. Also 19 of the sites had some kind of leachate collection system with treatment options, including disposal to existing sewers, recycling, and on-site treatment. One other key operational factor is the availability of cover material on-site. Only five of the sites visited had to purchase cover, a factor which greatly increased operating costs.

As discussed above, costs for wage rates, inflation, and discounting method were standardized. The actual wage rates, by system component are summarized in Exhibit 3-7. While there is a considerable range both within and among the components, the average rates are quite similar across the components. Exhibit 3-8 summarizes the assumptions which were used in calculating the standardized costs. Exhibit 3-9 shows the resulting average standardized costs for each component, along with sample sizes.

Exhibit 3-6

Average, Minimum and Maximum
Values for Operational Factors

Factor	Units	Average	Minimum	Maximum
Haul				
Distance	kilometers	14.5	2.4	40.2
Time per trip	minutes	43	15	90
Trips per day	-	2	1	4
Crew size	-	2	1	3
Percent of Work Day	%	18	6	38
Load/Trip	metric tons	4.7	1.4	9.1
Processing				
Design Capacity	metric tons/hr.	47	12	127
Operating Capacity	metric tons/hr.	27	1	98
Days Out of Service	day/year	25	0	300
Days Out of Operation	days/year	278	205	364
Transfer				
Vehicle Size	metric tons	23	9	45
Average Load	metric tons	16	1.8	36
Distance per Trip	kilometers	12	0.2	48
Time per Trip	minutes	53	5	210

Exhibit 3-6 (continued)

Factor	Units	Average	Minimum	Maximum
Landfill				
Design Capacity	metric tons/ day	815	45	4988
Average Weight Landfilled	metric tons/ day	644	15	4897
Lift Height	meters	3.6	0.6	17
Daily Cover	centimeters	14	0	30
Final Cover	centimeters	76	30	248
Days Operation	days/year	299	240	365

Exhibit 3-7

45-site average wage rates (without fringes).

	Average Over All Sites	Lowest Value	Highest Value	Sample Size
Collection	5.92	3.50	10.62	20
Large-vehicle transport	5.74	3.57	8.87	31
Processing	5.62	2.90*	8.21	28
Landfilling	5.66	3.27	8.82	42
Landfill construction	5.83	4.20	9.33	27

*Below minimum wage.

Exhibit 3-8

Assumptions for standardization of labor and capital costs.

Labor Assumption:	
Standard hourly wage	$ 5.33
Standard hourly fringe benefits	33%
Capitalization Assumptions:	
Moving equipment	5 years @ 10%
Stationary equipment	10 years @ 8%
Buildings	20 years @ 8%

Exhibit 3-9

Cost in dollars per metric ton.

	Sample Size	Average	Standard Deviation	Minimum	Maximum
Haul in collection vehicles					
capital	20	1.18	.79	.08	3.41
operating	20	5.67	3.97	.40	15.21
Total:	20	6.85	4.69	.47	18.62
Transfer stations					
capital	10	2.53	4.28	0	14.58
operating	10	7.22	10.60	.33	32.55
Total:	10	9.75	14.23	.83	47.12
Shredder					
capital	7	4.95	2.54	2.00	8.44
operating	8	5.63	2.52	2.31	9.48
Total:	7	11.06	3.75	6.49	17.93
Baler					
capital	11	9.58	5.82	1.45	19.76
operating	11	8.00	4.68	2.31	17.75
Total:	11	17.58	9.50	6.07	31.61
Haul in large vehicles after processing					
capital	20	2.15	3.26	.43	15.29
operating	18	3.30	2.39	.95	10.97
Total:	18	5.48	4.68	1.74	19.03
Landfilling					
capital	37	1.27	.90	.01	3.89
operating	36	3.20	3.47	.40	16.04
Total:	36	4.46	3.89	.84	19.92
Landfill Construction					
capital	24	1.34	2.09	.02	7.54
operating	23	1.14	1.95	.02	7.82
Total:	23	2.42	3.94	.07	14.97

Section 4

Modeling of Waste Management Costs

The processed data from Section 3 were used to model waste management costs, in accordance with the framework presented in section 2. Statistical and econometric techniques were used, primarily Ordinary Least Squares with some analysis of the error terms. The Statistical Analysis System (SAS) (reference 57) was used for estimation. The following sections describe general modeling issues (4.1), the haul models (4.2), the transportation models (4.3), the processing models (4.4), the landfilling models (4.5), and the attempts to model landfill construction (4.6). In addition, section 4.7 presents a process for estimating the effects of future cost increases for more remote sites, based on earlier work.

Metric units are used for all models.

4.1 General Modeling Issues

Statistical estimation is an imperfect process, and there is no procedure which guarantees a perfect analysis. Usually, we assume a simple form such as:

$$\text{Cost} = b_0 t \quad b_i x_i + \text{error} \qquad (1)$$

where cost is the sum of coefficients (b_i) times the independent variables (x_i) plus some unexplained error. R^2 and F-statistics are among the factors used to evaluate goodness-of-fit. Each coefficient is estimated, with some uncertainty measured by standard errors and t-tests. Care is needed in estimating a single equation -- the modeller must carefully test explanatory variables, with concern for specification, functional form, and data quality.

Correlation of Errors

When several equations interact, the problem becomes much more complex. For example, if the errors in two equations are correlated, this affects the properties of the estimators. In this case, two factors lead to interaction of the error terms: correlations within a site and mistakes in allocation. The former occur when, for some reason, all costs at a site are particularly high or low. For example, lack of preventive maintenance could increase vehicle costs for <u>all</u> steps in an area. If the specification is imperfect, the result could easily be correlated errors.

Now consider a site where a bulldozer is split between landfill operation and landfill construction. If an error is made in the estimate of time spent in each, this could increase the cost found for operation and decrease the apparent construction cost. Again, the errors will be correlated.

In the absence of a simultaneous equation structure, correlation of errors will lead to inefficient estimators, meaning that the error margins on each estimate will be broader than we could achieve, to some degree. However, this effect is likely to be small, and not worth the additional effort required for full-information estimation of the set of equations.

Measurement Errors

Any physical study is subject to measurement error. In this case, costs and cost allocations may be in error, and there are likely to be errors in the fractions of time spent in particular activities (e.g. 30% haul). Round trip times had a tendency to be provided in 15-minute intervals, and fractions in even amounts. Measurement errors reduce efficiency, and generally tend to bias coefficients towards zero. This is a known problem, and one which may reduce some of the projected costs to a small degree.

Misspecification

The models presented later in this chapter are all double log (constant elasticity) models, of the form

$$\text{Cost} = b_o x_1^{b_1} x_2^{b_2} \qquad (2)$$

This is a common form for a cost function, derivied from a production function, but the exponents generally lead to significant forecasting inaccuracies outside the range of the data. Linear and semi-log forms were also tested; fit and structure made the log-log form seem most appropriate.

If errors are made in the form of the model or in the variables included, the results may be affected. Omitted variables may lead to bias on the other coefficients, and a poor model. This is a standard problem; in this case, numerous other variables and forms were tested, and the models presented here appear to be the best match between the data and the theory.

Totals

At the start of the modeling, there were two options: develop an equation for total costs, and a method for sharing it among components; or, develop an equation for each individual cost component, and sum to get the total. After considering the data, it became apparent that the component model was appropriate for each step -- it was better to model transport separately from haul or landfill construction. However, the total cost models

for each step are probably best for forecasting, since there is a direct interaction between capital and operating costs. Note that, because of the model structure, there will usually be some error in adding capital and operating costs to get total; the capital and operating cost estimators should be considered rough curves for use in budgeting.

Standardization

Consider a system with very low labor rates and high costs for equipment. The operators will minimize costs by using many staff and little equipment. When costs are standardized, this system will appear to have high costs, even though that may actually be very well managed and inexpensive. This phenomenon could affect the modeling results. However, some of the models were run with both reported actual and standardized costs, and there was minimal effect on the results. Therefore, it appears that this is not a serious problem.

Summary

These issues have been considered throughout the model development and selection. Econometrics is not an exact science, and there is no guarantee that we have always made the right choices. However, we believe that the models presented below are the best which can be developed from the data and existing theory, along with our desire for simple models wherever complexity is not necessary. Exhibit 4-1 shows those results.

4.2 Haul Models

The haul models are very simple. The functional form for all three models is:

$$\text{Cost per ton} = 259.8\ (\text{Fraction of day in haul})^{1.66}(\text{tons per load})^{-.688} \quad (3)$$

Cost per ton rises if the time spent in haul increases, and falls if the collection truck carries more per load. In all cases, the collection crew accompanied the truck on the haul portion, so those labor costs are included. For the total cost model, a 1% increase in the time fraction (from, say, .30 to .303) will lead to a 1.7% increase in cost per ton. A 1% increase in tons per load will reduce cost by .7%.

It was anticipated that there might be significant differences in fuel use, maintenance, downtime, and the like for longer versus shorter hauls, or by type of vehicle (diesel vs. gasoline, manufacturer, etc.). These did not appear in the data.

The fit on the capital cost model was slightly inferior to the operating or total costs models, probably because the expenses come in larger discrete units.

Exhibit 4-1

MODELING RESULTS

Type	Model*	Statistics
Haul in collection vehicles		
capital:	ln(HCOSTC) = 3.46 + 1.43 ln(TIMFR) - .708 ln(TONLD) (.90) (.33) (.31)	R^2 = .54 F(17,3) = 9.95
operating:	ln(HCOSTO) = 5.49 + 1.76 ln(TIMFR) - .686 ln(TONLD) (.80) (.29) (.28)	R^2 = .67 F(17,3) = 17.48
total:	ln(HCOST) = 5.56 + 1.66 ln(TIMFR) - .688 ln(TONLD) (.80) (.29) (.28)	R^2 = .65 F(17,3) = 16.11
Transfer in larger vehicles		
capital:	ln(TCOSTC) = 7.00 + 1.38 ln(TIME) - .835 ln(TONS) (1.80) (.21) (.21)	R^2 = .70 F(14, 4) = 10.9
operating:	ln(TCOSTO) = 4.88 + .373 ln(TIME) - 6.86 ln(TONS) (1.71) (.20) (.20)	R^2 = .52 F(14,4) = 5.2
total:	ln(TCOST) = 6.86 + .287 ln(TIME) - .792 ln(TONS) + .794 ln(LOADS) (1.26) (.14) (.15) (.21)	R^2 = .77 F(14,4) = 15.3
Processing		
capital:	ln(PCOSTC) = 2.50 + 1.42 BALER + .874 SHREDDER + .53 ln(CAP) = .53 ln (HRS) (1.57) (.36) (.38) (.27) (.22)	R^2 = .71 F(19,5) = 11.8
operating	ln(PCOSTC) = 3.24 + 1.20 BALER + 1.05 SHREDDER + 2.1 ln(CAP) - .46 ln (HRS) (1.64) (.37) (.30) (.28) (.23)	R^2 = .61 F(19,5) = 7.6
total:	ln(PCOST) = 3.53 + 1.35 BALER + 1.01 SHREDDER + .341 ln(CAP) - .48 ln (HRS) (1.39) (.31) (.33) (.24) (.20)	R^2 = .73 F(19,5) = 12.6
Landfilling		
capital:	ln(LCOSTC) =1.53-.31 BALER-.41 SHREDDER-.40 ln(TONDAY)+.66 COVER+.89 PHASED (.84) (.36) (.59) (.14) (.70) (.44)	R^2 = .27 F(28,6) = 2.1

Exhibit 4-1 (continued)

Type	Model*	Statistics
Landfilling		
operating:	ln(LCOSTO) = 2.60 − .82 BALER − 1.66 SHREDDER − .19 ln(TONDAY) + 1.18 COVER − .70 PHASED (.48) (.20) (.33) (.08) (.40) (.25)	R^2 = .59 F(28,6) = 8.0
total:	ln(LCOST) = 2.88 − .57 BALER − 1.26 SHREDDER − .22 ln(TONDAY) + 1.00 COVER − .35 PHASED (.42) (.18) (.30) (.07) (.35) (.22)	R^2 = .54 F(28,6) = 6.5

DEFINITIONS OF MODEL VARIABLES

HCOST	haul cost per ton; suffix: (c) = capital (o) = operating; no suffix is total cost
TIMFR	fraction of vehicle and crew time spent hauling waste
TONLD	haul vehicle capacity, tons per load
TCOST	transfer in large vehicles, cost per ton
TIME	round trip travel time, minutes
TONS	total tons transferred per year
LOADS	transfer vehicle loads per day
PCOST	processing cost, $/ton
BALER	is the waste processed by a baler (0 = no, 1 = yes)
SHREDDER	is the waste processed by a shredder (0 = no, 1 = yes)
CAP	design capacity of processing facility, tons per hour
HRS	actual processing equipment operating hours, last fiscal year
LCOST	landfilling cost, $/ton
TONDAY	average landfill operation, tons per day
COVER	is cover purchased off site? (0 = no, 1 = yes)
PHASED	is landfill construction phased with landfilling? (0 = no, 1 yes)

*NOTE: all models estimated in English units. Standard errors are in () under coefficients.

Statistics:

R^2 = measures the percentage of variance "explained" by the model. It measures how well the model fits the data.

F - statistic is also a measure of goodness of fit. With 28 degrees of freedom and 6 variables, the critical 95% value is 2.45. Larger values mean that we are at least 95% confident that the model fits the data better than no model.

4.3 Transport Models

Transportation from transfer/processing to disposal occurred in a wide range of conditions, from within a site to many miles. However, the vehicles used were generally dedicated to this purpose, making accounting easier. The cost per ton depends on three key factors:

- o roundtrip travel time
- o tons per year
- o loads per day

Given similar coefficients on the last two factors, model 2 is:

$$\text{Cost/ton} = 953.4\ (\text{travel time})^{.29}(\text{tons per load})^{-.79} \qquad (4)$$

Longer travel times and smaller vehicles increase cost. Note that time was a much better determinant of cost than mileage, in part because of the labor component. In designing a system, choose the largest vehicles which can be kept effectively utilized. The transport model is sensitive to time, but less sensitive than the haul model, as expected.

4.4 Processing Models

The processing model is almost identical for transfer, shredding, and baling - the only difference is the constant. Separate models were developed, but gave very similar results; they were combined into a single model. Besides the technology choice, the two key parameters measure design capacity (in tons/hour) and actual operating hours. The basic results for total cost are:

$$\text{Transfer:}\quad \text{Cost/ton} = 34.1\ (\text{Capacity})^{.34}(\text{hours})^{-.48} \qquad (5a)$$

$$\text{Baling:}\quad \text{Cost/ton} = 131.6\ (\text{Capacity})^{.34}(\text{hours})^{-.48} \qquad (5b)$$

$$\text{Shredding:}\quad \text{Cost/ton} = 93.7\ (\text{Capacity})^{.34}(\text{hours})^{-.48} \qquad (5c)$$

One surprising result was the diseconomies of scale: processing was more expensive per ton in the larger facilities than the smaller ones, all else being equal. This held true as well for both operating and capital costs. The coefficients are barely significant, but it seems likely from the case studies that the larger facilities are much more complex. The complexity and operating problems (and urban locations) negate the expected cost savings.

The hours variable is a measure of both intensity of use (shifts per day) and downtime. If a facility is closed because of an explosion, for example, it loses hours. This is a key variable: for example, a 10% increase in hours would reduce the cost per ton by 5%.

4.5 Landfilling

This is the most complex of the models and, based on the F-statistic, the least successful. There are four key factors affecting cost:

- o type of waste (normal, baled, or shredded)
- o actual size of the operation (tons per day)
- o on or offsite cover
- o one-time or phased construction

Baled waste is cheaper to landfill than conventional waste, and shredded is cheaper still (partly because some of our sites were allowed to fill shredded waste without cover).

Scale economies exist, but they are not extreme. A 200 tons per day landfill is only 20% cheaper per ton than one at 100 tons per day, all else being equal. Purchasing offsite cover adds to the landfill operators typically buy cover and then haul it in their own vehicles, which also costs time.

Phased construction is cheaper. We believe that this is because phased construction allows efficient use of vehicles which would otherwise be idle on days where the wasteload was lower than average.

4.6 Landfill Construction

No acceptable models were developed for landfill construction. Costs were estimated, and explanatory variables included the need for leachate and gas control, roads, fences, and excavation, among other factors. However, we were unable to effectively describe either the pre-existing site conditions or the regulatory environment. Both appear to be critical factors. As discussed in Chapter 5, these should be estimated for each site, based on recent costs in that state.

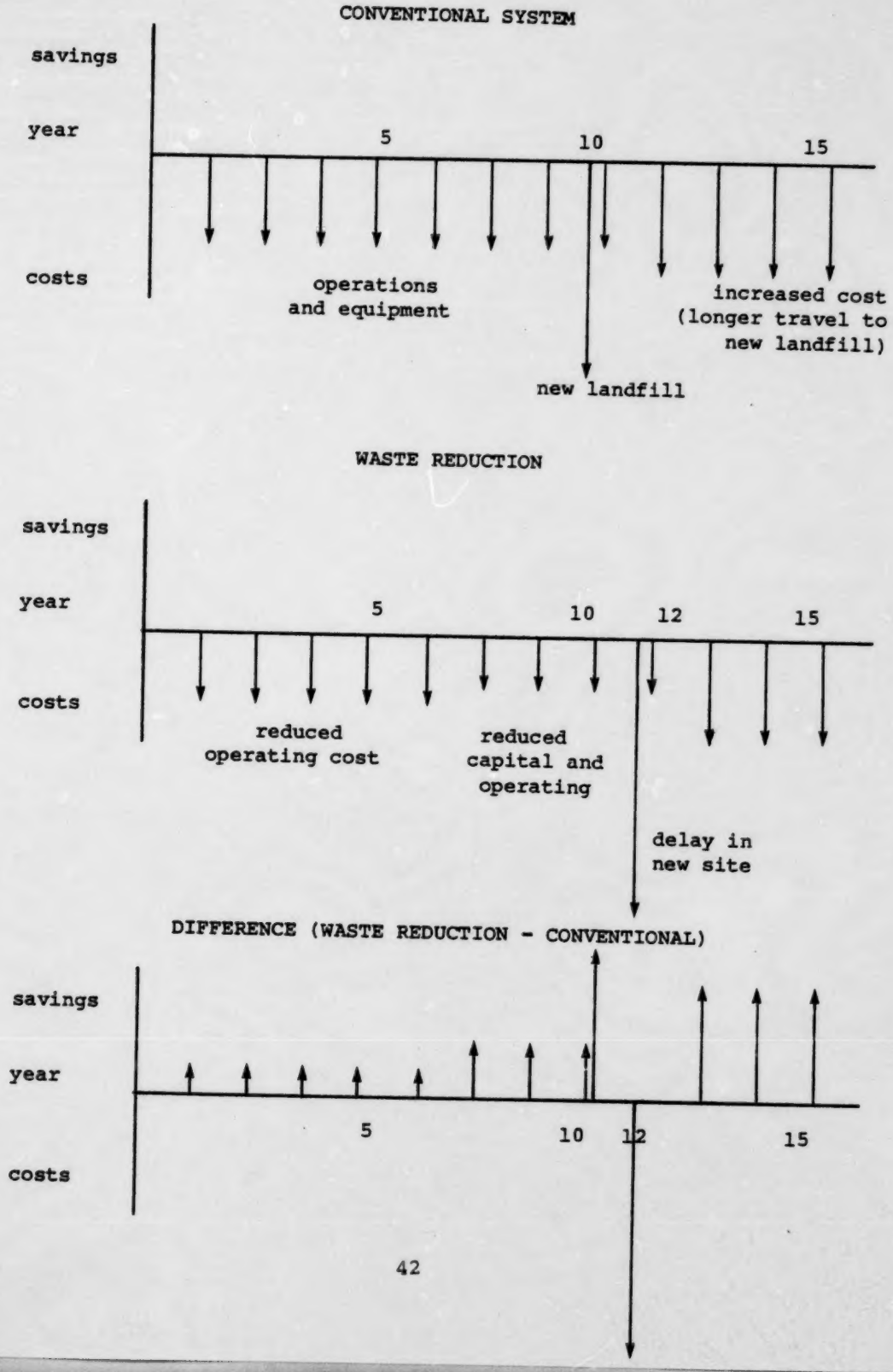
4.7 Next Sites and Waste Reduction

If a community can reduce the waste it generates, this will reduce waste management costs. Given our cross-section, the total cost results here should show long-term savings after adjustments in the number and type of equipment needed for the lower wasteloads. However, the operating cost savings should be available immediately. In addition, there will be savings in the next disposal site, simply because it will not be needed as soon. The money can gain interest in the meantime, and the next site will probably be further away increasing costs.

Exhibit 4-2 shows three cash flow diagrams. The first is a typical situation for a community which fills one landfill and starts another: costs increase. The second shows reduced costs because of waste reduction, while the third shows the differences. Even if the waste reduction requires a considerable investment, it could easily show net benefits.

Exhibit 4-2

Comparison of Cash Flows



Section 5

Application of the Cost Models

5.1 Introduction

The methods presented below are limited. They do not handle incinerators and resource recovery, though there are other cost studies which can be grafted on to this approach.[1] They become intractable when the number of alternatives is large, such as a region where there might be 5 or more transfer stations and processing plants. The number of possible transportation flows grows with the square of the number of sites, and that becomes difficult quickly.

The approach works best where there is a single landfill (which may be replaced by any of several possible new sites in a few years) and zero, one, or two transfer or processing facilities. This chapter focuses on that situation. The following questions are addressed:

- How will costs be affected by adding a transfer station?
- How will costs be affected by reductions in waste generated?
- How will costs be affected by adding baling or shredding?
- What will be the effect of increases in vehicle size for transfer or for collection/haul?
- How will a new landfill site affect total costs? More important, how will choosing any of several disposal options affect costs?

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[1] See section 2.

Typically, a manager might have a local landfill which is nearing capacity. The options might include

- Building a transfer station and transporting waste to a new remote landfill;
- Hauling waste directly to the new landfill;
- Shredding or baling the waste, either at a transfer station or at the new landfill;
- Disposing of the waste at a regional resource recovery plant, with either direct haul or transfer;
- Any of the above, plus a waste reduction program to get a few more years out of the existing landfill.

The case study in section 5.5 looks at exactly this situation, and compares costs for each of these options. Before presenting that case, though, we need to set the stage a bit more. Section 5.2 presents the modeling process. Section 5.3 then discusses sources for the necessary data to use the approach, and section 5.4 focuses on limitations and ways of testing the results to see if they are reasonable and fit common sense. The case study can provide a picture of how the approach works, but sections 5.2 through 5.4 are necessary reading for anyone who wants to apply this technique to a real problem.

5.2 The Modeling Process

There are three steps to this process: data collection, applying the models, and adjustment. Exhibit 5-1 presents the data needs for the modeling process. These data enable the models to be used, and adjusted for the real situation.

Exhibit 5-2 shows the solid waste flow from Exhibit 1-1, with one variation -- the transport of waste to a regional facility is allowed.

Any proposed system, must include costs per metric ton for each of the boxes used. For example, a system might include

- haul
- processing
- transport, and
- landfill.

Equations were developed in Section 4 for the cost of

- haul in collection vehicles,
- processing,
- haul in transfer vehicles, and
- landfilling.

Exhibit 5-1

Data Requirements

TIMFRAC - fraction of collection crew time spent in haul

TONLD - metric tons per load for collection vehicles

TIME - round trip travel time in minutes, transport

TONS - tons per year, transport

LOADS - loads per day transported

PHRS - operating hours per year, processing

PCAP - design capacity in metric tons per hour, processing

LTONDAY - landfilled metric tons per day

Engineering News Record Construction Cost Index, projected to the expected date of implementation

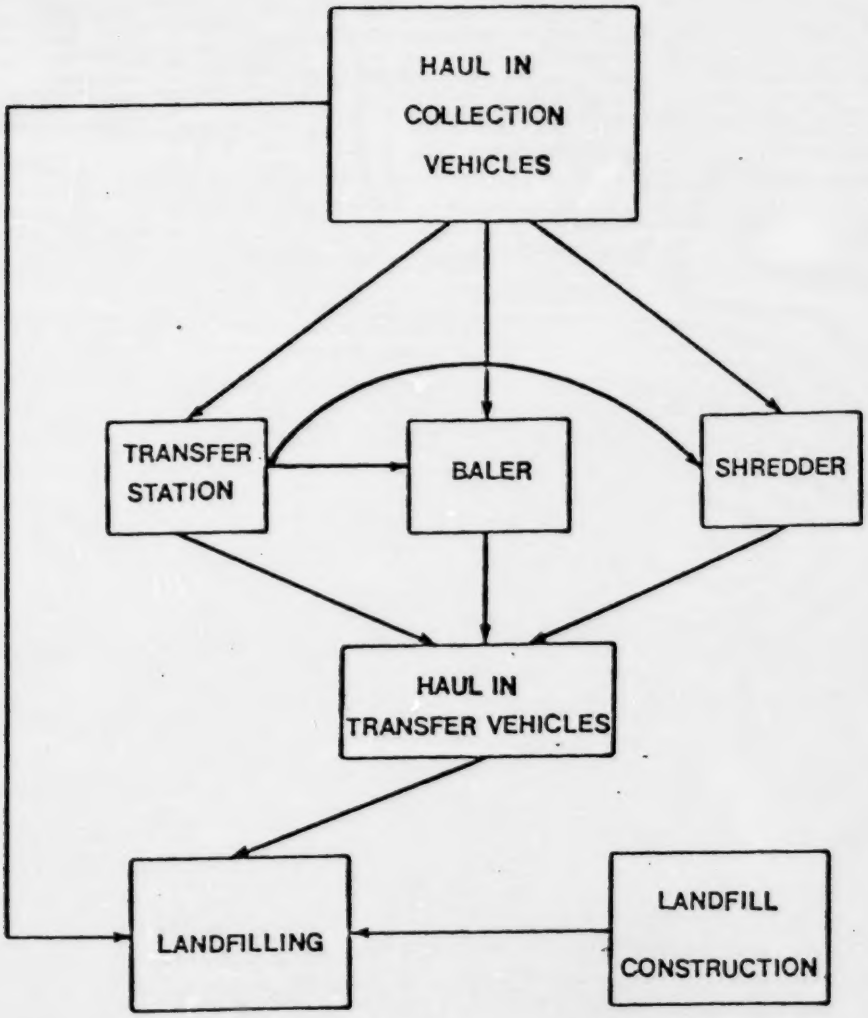
Landfill construction costs per metric ton of ultimate capacity (from engineering estimates). This includes pollution control costs.

Cost per metric ton for disposal at a regional facility (if any).

Actual labor and capitalization rates.

Exhibit 5-2

Disposal Process



Landfill construction costs are extremely site-specific, and require local engineering estimates for each site. Disposal at a regional facility simply requires a quoted price.

The four models are not perfect, but they are simple and easy to use. Use of these equations provides consistent relative comparisons, but does not provide accurate predictions of the actual future cost. The adjustment step (5.5) modifies the modeling results to more accuratley reflect future costs.

5.3 Data Sources

Metric Correction

Because of government policy, the models presented here use the metric system. All tonnages are in metric tons of 1,000 kg; roughly 2,200 pounds. To use English units, you need to make two adjustments:

- if you compute TONS
  TONLD
  PCAP
  LTONDAY

  in English units, multiply them by .91 before using the model equations.

- all costs computed from the models must be multiplied by .91 to bring them into $/(English ton) instead of $/metric ton.

TIMFRAC - the fraction of collection crew time spent in haul.

To compute this, you need to know the amount of time spent hauling waste on an average day and the amount of time the crew is paid. A crew's day includes the following components

1.	actual collection	_____ minutes
2.	haul (# of trips x round trip travel time)	_____ minutes
3.	lunch	_____ minutes
4.	start-up and cleanup	_____ minutes
5.	other breaks	_____ minutes
Total		_____ minutes

The fraction of time spent hauling waste is #2 divided by the total. For new sites with longer travel times, assume that total productive time stays constant, while haul time increases. Exhibit 5-3 shows an example.

Exhibit 5-3

Haul Time Fraction, Example

1) Existing System Average Day

	Total
Collection	365
Haul (25 minutes x 2 trips)	50
Lunch	45
Start-up/Cleanup	30
Other breaks	45
Total	510 minutes

This system uses a haul distance which is an average of 10 minutes from the landfill, plus 5 minutes dumping time.

TIMFRAC = 50/510 = .098

2) New system (longer haul, so shorter collection)

collection	325
haul (45 minutes x 2 trips)	90
lunch	45
start-up/cleanup	30
other breaks	45
Total	510

TIMFRAC = 90/510 = .176

TONLD - haul vehicle metric tons per load

If you currently have scales, this is easy to compute: it is simply the number of tons delivered in the last year divided by the number of loads. If you do not have scales, try to locate a set you can use, and measure weights for a week for at least 3 separate crews. That will be close. Failing all real data, use 400 lbs/yd^3 times the vehicle capacity (typical vehicles do better, but are not always full).

TIME - Minutes per transport round trip

Round trip travel time, in minutes, from the transfer station or processing plant to the landfill or facility. This includes outbound travel, unloading, and inbound travel, but not loading. Measure it by driving a large vehicle (not a car) in typical traffic conditions.

TONS - Transport vehicle metric tons per load

This is the number of tons per year transported. Calculate it based on expected waste generation and the transfer station used.

LOADS - Number of transport loads per day

Transport vehicle trips per day. If actual data is not available, divide the total tons per year by the estimated size of the individual loads. Remember that trucks rarely operate 100% capacity. You will need to assume a density. The average actual density for transported waste for the 45 sites was 500 lb./yd^3 (0.28tons/m^3).

PHRS - Processing hours

Hours the processing facility will operate per year. Actual data if possible; failing that, make a reasonable estimate considering downtime, seasonal variations, and rated capacity.

PCAP - Processing capacity

Manufacturer's rated capacity of the processing equipment, in tons per hour. Obtain this from the equipment manufacturer.

BALER

Does this processing facility contain a baler, used for 80% or more of the waste

If yes, BALER = 1
If no, BALER = 0

SHREDDER

Same as above, but for shredder systems.

LTONDAY

Landfill quantity in tons per day. Get actual data from existing sites where possible, make estimates for future sites.

COVER

Does off-site cover have to be purchased?

if yes, COVER = 1
if no, COVER = 0

(but, see "adjustments" in section 5.5)

PHASED

Was landfill constrution primarily performed at the beginning or is it phased with use?

if at beginning, PHASED = 0
if phased with use, PHASED = 1

5.4 Model Calculations (metric)

Haul Model

The total cost model is

$$\$/ton = 259.8\ (TIMFR)^{1.66}\ (TONLD) - .688$$

If TIMFRAC = .15 and
TONLD = 10

then $\$/ton = 259.8\ (.15)^{1.66}\ (10) - .688 = \$2.28.$

Transport Model

The total cost model is

$$\$/ton = 953.4\ (TIME)^{.287}\ (TONS) - .792\ (LOADS)^{.794}$$

If TIME = 90
TONS = 50,000
LOADS = 6

then $/ton = 2.69

Processing Model

$/ton = 34.1 (3.86 BALER) (2.75 SHREDDER) (CAP) $^{.341}$ (HRS)$^{-.481}$

if transfer station, with
PCAP = 50 tons/hour
PHRS = 2,000 hrs/year

then $/ton = 34.1 (50)$^{.341}$ (2000)$^{-.481}$ = $3.34/ton

if Baler, 3.34 x 3.86 = $12.91/metric ton
if Shredder, 3.34 x 2.75 = $9.20/metric ton

Landfilling Model

$/ton = 17.81 (.57 BALER) (.28 SHREDDER) (LTONDAY) $^{-.22}$
(2.72 COVER) (.71 PHASED)

if 200 tons per day phased landfill, on-site cover,

$/ton = 17.81 (200)$^{-.22}$ (.71) = 3.94/ton
if not phased 5.55/ton
if phased, and balefill 2.25/ton
if phased, and shredded waste fill 1.10/ton

5.5 Adjustments

To All Models - ENR Correction

The models were calibrated using an ENR Construction Cost Index of 3049 (July 1979). All costs should be multiplied by

$$\frac{\text{(Current or projected ENR)}}{3049}$$

For example, assume you project a design value ENR of 7000. Then

Cost/ton (design) = cost/ton (1979) x 7000/3049

or Cost/ton (design) = 2.30 (estimated cost from the models)

For future planning, you will need to estimate a reasonable future value of the ENR. (A value was probably assumed by the engineers who estimated landfill construction costs). Remember, this adjustment applies to all the estimated equations.

To All Models - Labor and Capital Assumptions

Your labor rates and capital cost treatments may be different than those assumed in estimating the models. The standardized labor rate used was $5.33/hour, with 33% fringes. Correct this using the current ENR, and compare your rates. If your average rate is within 25% of this value, do not make any corrections. If it is outside of that range, consider making the corrections shown in Exhibit 5-4.

For capital costs, we assumed the following depreciation schedule:

o moving equipment	5 years @ 10%
o stationary equipment	10 years @ 8%
o buildings	20 years @ 8%

These are real dollar (minus inflation) interest rates. To determine if the rates you are paying are approximately the same as those used in the model, you must calculate the real dollar component. Subtract the current rate of inflation from the rate you are paying to calculate the real dollar (minus inflation) interest rate. For example, if you are paying 15% on a mortgage and the inflation rate is 7%, then the real dollar interest rate is 8%. If your rate differs from the standard rate by more than 3%, you may want to adjust the figures. Similarly, if our depreciation schedule is very different from yours, you may wish to adjust. For example, if you assume

- o moving equipment lifetimes of less than 3 or more than 8 years
- o stationary equipment lifetimes less than 7 or more than 15 years
- o building lifetimes less than 15 or more than 30 years

These adjustments are somewhat complex. The starting point is the percentage of the cost per ton which is, on the average,

- o moving equipment capital cost
- o stationary capital cost
- o building capital cost (see Exhibit 5-5)

You then need a capital recovery table to get the capital recovery factor (crf) for your real dollar interest rate (minus inflation) and lifetimes. Then compute the ratio of your crf values to the assumed crf values. Finally, apply the equation in Exhibit 5-5 with the fractions and ratios to get the change in costs.

Exhibit 5-4

Labor Cost Corrections

Corrected haul cost = (Estimated haul cost) (.426 + .574 labratio)

transport = (Estimated transport cost) (.731 + .269 labratio)

processing = (Estimated processing cost) (.744 + .256 labratio)

landfilling = (Estimated landfilling cost) (.583 + .417 labratio)

where labratio = $\frac{\text{Your labor cost}}{\text{Our assumed labor cost}}$

Exhibit 5-5

Capital Accounting Adjustments (with example)

(a) Capital Cost Fraction of Total Cost

	Moving	Stationary	Buildings
Haul	.17	0	0
Transport	.40	0	0
Processing	0	.40	0
Landfilling	.04	.24	0

Assumed crf, moving: .2673
crf, stationary: .1512
crf, buildings: .1044

Your interest rate (i) moving - ___ % inflation = _____
stationary - ___ % inflation = _____
buildings - ___ % inflation = _____

Your depreciation period in years (n) moving _____
stationary _____
buildings _____

Given i and n, your crf moving _____
stationary _____
buildings _____

ratio of crf's (yours/assumed) moving: _____
stationary: _____
buildings: _____

Adjusted cost = unadjusted cost x (1 + (moving crf ratio - 1) (moving fraction)

+ (stationary crf ratio - 1) (stationary fraction)

+ (building crf ration - 1) (building fraction))

Example: moving equipment for transport lasts 10 years, everything else is okay.

i = 17% - 7% inflation = 10%
n = 10
crf (10%, 10) = .1627
crf ratio = .1627/.2673 = .61
unadjusted cost = $10/ton
adjusted cost = $10 (1 + (.61-1) (.40)) = $8.44/ton

D. Specific Model Adjustments: Haul

If the haul crews do not travel with the vehicles, but keep collecting instead, then the model will overestimate haul operating costs. Compute TIMFR for the crew as a whole, assuming only the driver travels, and use that in the operating cost model, using the basic TIMFR for the capital cost model.

E. Specific Model Adjustments: Landfilling

If you can estimate the cost per ton landfilled of purchased off-site cover, use that instead of the "COVER" variable. Set COVER = 0 and add in the off-site cover cost as an adjustment.

5.6 A Case Study

A community is running out of landfill space, and will need a new site in 5 years. The location of the new site has been selected, but it is further from town. They want to consider the following options:

- direct haul to the new site
- building a processing facility at the old site, with haul to the new site (transfer, shredder, baler)
- direct haul to a regional resource recovery facility
- transfer to the regional facility
- waste reduction to delay closing the old site, followed by any of these questions.

The following numbers are set:

current TIMFRAC (45 minutes round trip)	= .2
current hauls tons per load TONLD	= 6 tons
direct haul TIMFRAC	= .45*
transport time TIME	= 90 minutes*
transport tons TONS	= 50,000 tons
transport loads LOADS	= 6 loads/day
design capacity CAP	= 40 tons/hour
processing hours HRS	= 2,000 hrs/year
landfill tons/day LTONDAY	= 200 tons/day
cover COVER	= No (0)
phased construction PHASED	= Yes (1)
Projected ENR (1987)	= 6086
Projected ENR (1990)	= 7000
Life of existing landfill	= 5 years
Life with 40% waste reduction	= 8 years
Regional facility cost/ton	= $22.50 in 1987
Landfill construction cost/ton (1987)	= $ 7.75 in 1987

*to either new landfill or regional facility.

A. Current System

Haul in collection vehicles:	$10.48
Landfilling:	$7.82
Landfill construction:	$ 0 (fully amortized, old site)
TOTAL	$18.30 (1987 dollars)

B. New System, Direct Haul

Haul in collection vehicles	40.24
Landfilling:	7.82
Landfill construction:	7.75
TOTAL	55.86

C. New System, Transfer at Old Site

Haul in collection vehicles	10.48
Transfer station	6.24
Transport	5.38
Landfilling	7.82
Landfill construction	7.75
TOTAL	37.67

D. New System, Baler at Old Site

Haul	10.48
Baler	25.16
Transport	5.38
Landfilling	4.42
Landfill construction	7.75
TOTAL	53.19

E. New System, Shredder at Old Site

Haul	10.48
Shredder	21.78
Transport	5.38
Landfilling	2.22
Landfill construction	7.75
TOTAL	47.61

F. Haul to Regional Facility

Haul	40.24
Disposal	22.50
TOTAL	62.74

G. Transfer to Regional Facility

Haul	10.48
Transfer	6.24
Transport	5.38
Disposal	22.50
TOTAL	44.60

Exhibit 5-6 compares these alternatives. The lowest apparent cost is for transfer to the new landfill, which saves transportation costs without adding large processing costs. However, two other options (shredding and transfer to the regional facility) are within 30% of the lowest value, which is within the limits of reasonable accuracy for the models. Those three options deserve more detailed cost analyses, to decide which will have the lowest actual cost.

Evaluating Waste Reduction

Reducing the quantity of waste requiring disposal may have several effects on cost. It may make collection less efficient by requiring more travel per ton, and therefore reduce the number of haul trips per vehicle day. For any given level of processing, it may mean less efficient use of the facility, and fewer trips per vehicle for transport. At the landfill, the cost per ton may rise as the number of tons falls, because of fixed costs for equipment and inefficiencies in using labor. However, total cost should fall, and the landfill will last longer. For option C, transfer to a new landfill, it is useful to evaluate the effect of reducing waste quantities by 40%, about the maximum that could be expected from an extensive recycling program. Waste per day goes from 200 to 120 tons. This has three effects:

- It reduces operating costs in the short term (for example, the first five years);
- It extends the life of the existing landfill;
- It reduces capital costs in later years, since less equipment is needed.

All costs are in dollars based on the projected 1987 ENR value of 6086, but the cash flows on a year by year basis must be considered to get a useful comparison. Assume the following:

- TIMFRAC increases to 0.25

Exhibit 5-6

COMPARISON OF ALTERNATIVES ($/ton)

	Haul	Processing/ Transfer	Transport	Landfill	Total
A. Current	10.48	0	0	7.82	18.30
B. Direct Haul	40.24	0	0	15.57	55.81
C. Transfer*	10.48	6.24	5.38	15.57	37.67
D. Baler	10.48	25.16	5.38	12.17	53.19
E. Shredder	10.48	21.78	0	9.97	47.61
F. Haul/ Regional	40.24	0	0	22.50	62.74
G. Transfer/ Regional	10.48	6.24	5.38	22.50	44.60

*Least Cost Alternative

- o the transfer facility can be reduced to 25 tons/hour (CAP)

- o the operator must continue to pay the current capital costs for the next 5 years. If the capital cost for haul is $1.80/ton, this is $90,000/year which must be paid -- even if those vehicles are not needed for the lower volume.

- o reduced fleet sizes, etc., take effect in the 6th year.

Therefore, for years 1-5 there are some operating cost savings from the operating cost model in chapter 4; cost per ton rises, but total cost falls. For years 6-8, the operators continue to save on operating costs, plus capital costs, and the delay in the new landfill. Years 9-20 show operating and capital cost savings.

Without waste reduction

Years 1-5, 50,000 tons per year @ $18.30, or $915,000 per year.

Years 6-20, 50,000 tons per year @ $37.67/ton, or $1,883,000 per year.

With Waste Reduction

Years 1-5: (no adjustment in capital; total $ capital costs remain constant)

Haul operating costs are	$12.36/ton;
Haul capital costs are	$ 3.00/ton;
Landfilling oper. costs are	$ 5.38/ton;
Landfilling capital costs are	$ 4.64/ton;
TOTAL COSTS PER TON:	$25.38.

30,000 tons per year gives $761,000 per year.

Years 6-8: (capital cost adjustments made in vehicles)

Haul costs per ton:	$15.17
Landfilling costs per ton:	$ 8.76
TOTAL COSTS PER TON:	$23.93

30,000 tons per year gives $718,000 per year.

Years 9-20: Transfer to new landfill

Haul costs per ton:	$15.17
Transfer costs per ton:	$ 8.18
Transport costs per ton:	$ 5.32
Landfilling costs per ton:	$ 8.76
Landfill construction costs/ton	$ 7.75
TOTAL COSTS PER TON:	$45.18

30,000 tons per year gives $1,355,000 per year.

Therefore, a comparison of the before and after waste reduction results gives us the following annual cash flows:

	Before	After
Years 1-5	$915,000	$761,000
Years 6-8	$1,883,000	$718,000
Years 9-20	$1,883,000	$1,355,000

The present value of waste reduction at a 10% interest rate is over $4 million. If you could implement a waste reduction program today at this site, for a cost of less than $4 million, you would wind up saving money. All of this analysis, of course, is based on the models and their treatment of waste quantities, but the results should be indicative of reality. This analysis did not consider salvage value at year 20, which would further add to the value of waste reduction. At that point, the "without" case has placed 750,000 tons in the new landfill while the"waste reduction" case has placed only 360,000. This delays the need to utilize the next-site even further.

Appendix A

DESCRIPTIONS OF THE CASE STUDIES

CASE # 1

Type: . . . . . Baler
State: . . . . . Ohio

Labor Rate/hr: . . . . $4.48-$4.98
Annual rainfall,cm: . . . 106

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 45
Processed, MT/day: . . . 349
Cost/MT: $10.24
Average bale size, MT: . 1.18

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 16.3
distance, km: . . . 0.8
Cost/MT: $0.70
Vehicle: . . 15 MT flat bed tractor trailer

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 60.7
Operations costs/MT: . $0.76
Quantity landfilled, MT: 454
Construction costs, $/MT/day: $1.32
leachate collection: . . none
Type of liner: . . . natural clay
Source of cover: . . . . on-site

This county facility includes a baler and landfill on the same site. Waste is delivered by municipal and private haulers, and some private vehicles. Most wastes are baled. Approximately 5% of the wastes including items such as liquids, plastic scraps, and loads of tires are landfilled directly.

Overall operating costs at this facility were very low. Each of the three operational components analyzed, processing (baling), transfering, and landfilling, have costs considerably below average. Processing costs are relatively low because the baling facility runs at near capacity for an eight hour day. Transfer costs are minimized because the processing facility is located at the landfill site approximately one half mile (.8 km) for the operating face. Bales are transfered directly from the processing facility to the operating face with minimal storage.

The landfill is on clay with natural clay liner and cover. Landfilling costs are also below the average for a facility handling bales for several reasons: use of some army surplus equipment, no placement of daily cover, and the lack on any permanent facilities at the landfill.

CASE # 2

Type: . . . . . Shredder
State: . . . . . New York

HAULING (COLLECTION VEHICLES)

Ownership . . . . . Public
Load, MT: 6
Haul distance, km . 11
Cost/MT: $4.65
% of time in Haul . 16%

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 15.5
distance, km: . . . 16
Cost/MT: $3.20
Vehicle: . . 10 wheel tractor trailer

Labor Rate/hr: . . . . . $4.70-$5.55
Annual rainfall,cm: . . . 126

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 41
Processed, MT/day: . . . 418
Cost/MT: $5.91
Partical size, cm: . . . 8

LANDFILL

Ownership: . . . . . Private
Method: . . . . . Area
Fillable area, ht: . . . 59
Operations costs/MT: . . $ NA
Quantity landfilled, MT/day: 680
Construction costs, $/MT: $ NA
Leachate collection: . . partial
Type of liner: . . . . . clay
Source of cover: . . . . on-site

Three different organizations cooperate to operate this solid waste management system. The haul component is run by the city; the shredding facility is run by the county; and a private firm operates the landfill. Despite the multi-organizatonal structure, this sytem is quite efficiently operated.

The haul component consists of a 3-person crew, single shift operation with work incentives. The city has excellent data on the operation of the haul component and is using this informtion to examine alternatives such as one-person crews or different hauling methods.

The county operates two transfer-shredding facilities. Because of operating problems, only about 180 of the 420 tons processed daily at the main facility is shredded. The remaining waste is simply transferred to larger vehicles for transfer to the landfill. The secondary facility has similar problems and shreds even less waste.

Finally, a private firm operates the landfill by the "experience method", rather than according to any engineered site design. The facility has permit, funding, and equipment problems.

CASE # 3

Type: . . . . . Shredder
State: . . . . . Ohio

Labor Rate/hr: . . . . $ NA
Annual rainfall,cm: . . . 111

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load/MT: 4
Haul Distance, km . 11
Cost/MT: $7.30
% of time in Haul . 20%

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 54
Processed, MT/day: . . . 884
Cost/MT: $11.85
Average partical size,cm: 5

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 15
distance, km: . . . 19
Cost/MT: $4.20
Vehicle: . . 27 ton open back tractor trailer

LANDFILL

Ownership: . . . . . Private
Method: . . . . . Area
Fillable area, ht: . . . 71
Operations costs/MT: . $ NA
Quantity landfilled, MT/day: 1,995
Construction costs, $/MT: $ NA
Leachate collection: . . discharge to sewer
Type of liner: . . . . . clay
Source of cover: . . . . on-site

This solid waste management system is a combination of public and private facilities. The haul and processing components are municipal owned and operated, while a private firm owns the landfill.

This municipality operates three shredder-transfer stations, all built at the same time and with large mining equipment. Except for unusual situations (e.g., sending drums of contact cement through the system), the facilities have operated well.

A subsidiary of a large national waste management firm operates the current disposal site, so some data were proprietary.

This is one of our largest sites -- about 2000 tpd. The firm maintains records of the wastes volumes rather than weights, because they feel that the entering volume was the best measure of the volume in fill that determined their costs.

CASE # 4

Type: . . . . . Transfer
State: . . . . . Maine

Labor Rate/hr: . . . . . $2.90-$5.50
Annual rainfall,cm: . . 134

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Private
Rated Capacity, MT/hr: . NA
Processed, MT/day: . . . 3.6
Cost/MT: $18.25

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Private
MT/load: 6.3
distance, km: . . . 8
Cost/MT: $14.02
Vehicle: .

LANDFILL

Ownership: . . . . . Private
Method: . . . . . Area
Fillable area, ht: . . . 28
Operations costs/MT: . $7.52
Quantity landfilled,
MT/day: 111
Construction costs, $/MT: $0.57
Leachate collection: . . none
Type of liner: . . . . . clay
Source of cover: . . . . on-site

This small community solid waste management system is a unique mix of private ownership and public operation. The haul component is performed by several small private contractors. The transfer station and landfill are both owned by a private firm. The municipality leases and operates the transfer station and pays the firm a flat tonnage rate for haul in large vehicles and landfilling.

CASE # 5

Type: . . . . . Shredder
State: . . . . . Maine

Labor Rate/hr: . . . . $4.14-$4.82
Annual rainfall,cm: . . . 140

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 36
Processed, MT/day: . . . 112
Cost/MT: $9.23
Average particule size,cm 23

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 14
distance, km: . . . 0.2
Cost/MT: $1.53
Vehicle: . . 18 ton open back tractor trailer

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 11.4
Operations costs/MT: . $1.09
Quantity landfilled, MT/day: 111
Construction costs, $/MT: $0.06
leachate collection: . . none
Type of liner: . . . . . none
Source of cover: . . . . on-site

This solid waste management system is publicly-owned and operated by the city Department of Public Works. The city hauls the majority of the waste although there a few commercial haulers. Two other communities have contractual arrangements to haul waste to the processing facility.

All waste must be delivered to the processing facility where it is then transferred in large vehicles to municipally-owned and operated landfills. Approximately 95% of the waste is shredded.

CASE # 6

Type: . . . . . Transfer
State: . . . . . Maine

Labor Rate/hr: . . . . $4.00-$5.00
Annual rainfall,cm: . . . 104

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . NA
Processed, MT/day: . . . 3.8
Cost/MT: $42.84

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Private
MT/load: 13
distance, km: . . . 34
Cost/MT: $17.30
Vehicle: . . 15 ton open back tractor trailer

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 2.8
Operations costs/MT: . $ NA
Quantity landfilled, MT/day: 75
Construction costs, $/MT: $ NA
Leachate collection: . . none
Type of liner: . . . . . clay
Source of cover: . . . . on-site

This small community solid waste management system consists of a $60m^3$ self-compacting trailer. 80% of the waste is hauled by private residents while the remaining 20% is hauled by small private contractors.

The municipality owns and operates the transfer facility as a public service at no charge to the residents. The municipality pays a private firm to haul the trailer to a landfill site in a neighboring community about once a week. The community hopes to develop an RDF steam generating facility in the future.

CASE # 7

Type:	Shredder	Labor Rate/hr:	$3.27-$5.50
State:	North Carolina	Annual rainfall,cm: . . .	130

HAULING (COLLECTION VEHICLES)

Ownership:	Public
Load, MT:	3.7
Haul Distance, km: .	4.0
Cost/MT:	$8.78
% of time in Haul .	24%

PROCESSING

Ownership:	Public
Rated Capacity, MT/hr: .	36
Processed, MT/day: . . .	136
Cost/MT:	$7.51
Average particle size,cm	NA

TRANSFERING (LARGE VEHICLES)

Ownership:	Public
MT/load:	16
distance, km: . . .	0.5
Cost/MT:	$0.81
Vehicle: . .	54 ton flat-bed tractor trailer

LANDFILL

Ownership:	Public
Method:	Uncovered
Fillable area, ht: . . .	16
Operations costs/MT: .	$0.99
Quantity landfilled, MT:	300
Construction costs, $/MT:	$ NA
Leachate collection: . .	none
Type of liner:	none
Source of cover:	on-site

This solid waste management system is an example of intergovernmental cooperations. Two municipalities and the surrounding county have entered into a tri-governmental agreement creating a single waste management system. This case study examined a processing facility which is owned by the county, but leased to the city.

The city's sanitation department has the primary role for the Haul component. Industrial and commercial haulers pay a tipping fee while private residents may use the facilities free of charge.

The shredder which is located at the landfill processes approximately 45% of the waste. There have been considerable operational problems, causing the shredders to be out of commission for over 90 days in 1979.

The landfill is an uncovered shred-fill. The lack of a requirement for daily cover helps reduce costs.

CASE # 8

Type:	Shredder	Labor Rate/hr:	$3.57-$6.15
State:	North Carolina	Annual rainfall,cm: . . .	91

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership:	Public
Rated Capacity, MT/hr: .	18
Processed, MT/day: . . .	98
Cost/MT:	$11.01
Average particle size, cm	8

TRANSFERING (LARGE VEHICLES)

Ownership:	Public
MT/load:	17
distance, km: . . .	0.3
Cost/MT:	$1.01
Vehicle: . .	27 ton flat-bed

LANDFILL

Ownership:	Public
Method:	Area
Fillable area, ht: . . .	20
Operations costs/MT: .	$8.44
Quantity landfilled, MT:	169
Construction costs, $/MT:	$ NA
leachate collection: . .	none
Type of liner:	none
Source of cover:	on-site

This solid waste management system consists of a shredder and landfill at one site. The facilities are owned and operated by the county as a public service to county residents. The Haul component is the responsibility of the individual residents or private contractors.

Other commercial users and U.S. military haulers acccount for 16-20% of the wastes.

CASE #9

Type: . . . . . Shredder
State: . . . . . South Carolina

Labor Rate/hr: . . . . $4.00-$4.88
Annual rainfall,cm: . . . 147

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 72
Processed, MT/day: . . . 329
Cost/MT: $16.30
Average particle size, cm 10

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 15
distance, km: . . . 1.6
Cost/MT: $1.91
Vehicle: . . 17 ton flat-bed

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 51
Operations costs/MT: . $1.15
Quantity landfilled, MT: 181
Construction costs, $/MT: $ NA
Leachate collection: . . none
Type of liner: . . . . . none
Source of cover: . . . . on-site

This solid waste management system consists of a shredder located at a landfill site. The haul component of the system is performed by nine municipalities and several private haul contractors. All the wastes are delivered to the shredding facility where approximately 5% is sorted out and sent to the landfill unprocessed.

The shredder is owned and operated by the county as a public service to the municipalities. The private hauler pays a tipping fee. The shredding facility is quite capital intensive and operates at about 67% capacity. The county also ownes and operates the large transfer vehicles as part of the overall waste management system.

The landfill is owned by a private company, but leased and operated by the county. The landfill operates with no daily cover, greatly reducing the labor and equipment requirements. The facility handles approximately 180 tpd with only two vehicles.

CASE # 10

Type: . . . . . Transfer
State: . . . . . South Carolina
Labor Rate/hr: . . . . $3.75-$5.73
Annual rainfall,cm: . . . 150

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load, MT: 3.3
Haul Distance, km . 9
Cost/MT: $9.44
% of time in Haul . 14%

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . NA
Processed, MT/day: . . . 144
Cost/MT: $3.39

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 18
distance, km: . . . 32
Cost/MT: $4.35
Vehicle: . . 11 ton open-back

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Trench & fill
Fillable area, ht: . . . 87
Operations costs/MT: . $2.54
Quantity landfilled, MT: 453
Construction costs, $/MT: $1.76
leachate collection: . . none
Type of liner: . . . . . none
Source of cover: . . . . on-site

This is a typical regional solid waste mangement system, where the landfill is owned and operated by the largest government in the area, in this case, a city. The city maintains a fleet of haul trucks which serve both the city and other municipalities. Private haulers provide service on a contractual basis to other areas.

Approximately 34% of the waste handled by the system passes through a transfer station located in the city. The wastes are compacted and loaded into transfer vehicles for the 32 kilometer trip to the landfill.

The traditional area landfill receives wastes from the transfer station, haul vehicles, and private residents. The current design calls for a single 11 meter lift.

CASE # 11

Type: . . . . . Shredder
State: . . . . . Florida

Labor Rate/hr: . . . . $3.99-$4.54
Annual rainfall,cm: . . . 150

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 91
Processed, MT/day: . . . 790
Cost/MT: . . . . . $ NA
Average bale size, MT: . 8

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 36
distance, km: . . . 1.6
Cost/MT: $1.50
Vehicle: . . 45 ton flat-bed

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Above-grade
Fillable area, ht: . . . 1.3
Operations costs/MT: . $ NA
Quantity landfilled, MT: 794
Construction costs, $/MT: $ NA
Leachate collection: . . on-site
Type of liner: . . . . . PVC
Source of cover: . . . . on-site

This is a county owned and operated solid waste management system. The system is set up as a utility district with a completely separate budget. Each resident pays an annual fee, as a separate line item on the property tax bill.

The haul component is performed by five municipalities, three franchise collectors, and small contractors. There are some transfer stations in the system, although these were not included in this study.

The shredding facility which is located at the landfill experienced extrem operational problems. As a result, the shredder operated very few days during the year for which data was collected, and most of the waste was landfilled unprocessed. This is an above ground landfill with leachate collection system.

CASE # 12

Type: . . . . . Direct Haul
State: . . . . . Florida

Labor Rate/hr: . . . . $4.25-$5.70
Annual rainfall,cm: . . . 155

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load, MT: 9
Haul Distance, km . 13
Cost/MT: $0.43
% of time in Haul . 11%

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

Not applicable

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Above-grade
Fillable area, ht: . . . 46
Operations costs/MT: . $18.11
Quantity landfilled, MT: 227
Construction costs, $/MT: $ NA
Leachate collection: . . Recycling
Type of liner: . . Asphalt & Sand
Source of cover: . . . . on-site

This solid waste management system has only haul and landfill components. The county bills its residents a flat fee on the property tax bill for solid waste management. Most of this fee is paid out to ten franchised haulers. Waste is delivered directly to the landfill.

The above ground landfill has a leachate collection system. The fill is constructed in two foot (60 cm) lifts with six inches (15 cm) of daily cover and a final cover of two feet (60 cm), to reach the anticipated height of 16 feet (5 m).

CASE # 13

Type:	Direct Haul	Labor Rate/hr:	$3.50-$6.00
State:	Florida	Annual rainfall,cm: . . .	127

HAULING (COLLECTION VEHICLES)

Ownership:	Private
Load, MT:	NA
Haul Distance, km .	29
Cost/MT:	$ NA
% of time in Haul .	11%

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

Not applicable

LANDFILL

Ownership:	Public
Method:	Above-grade
Fillable area, ht: . . .	141
Operations costs/MT: .	$3.93
Quantity landfilled, MT:	330
Construction costs, $/MT:	$ NA
Leachate collection: . .	Recycling
Type of liner:	Natural Clay
Source of cover:	on-site

This is a simple direct haul solid waste management system. The haul component is provided by the county as a public service. Residents pay a fixed monthly fee on their tax bills. The haul compontent is performed by two franchised private collectors.

The above ground landfill has a leachate collection system. The fill is constructed in two foot (60 cm) lifts with six inches (15 cm) of daily cover and a final cover of two feet (60 cm).

CASE # 14

Type: . . . . . Transfer
State: . . . . . Florida

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load, MT: 2
Haul Distance, km . 5
Cost/MT: $16.92
% of time in Haul . 20%

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 21
distance, km: . . . 21
Cost/MT: $2.50
Vehicle: . . 34 ton modified flat-bed

Labor Rate/hr: . . . . $4.00-$4.30
Annual rainfall,cm: . . . 120

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 20
Processed, MT/day: . . . 65
Cost/MT: $0.74

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Trench & fill
Fillable area, ht: . . . 116
Operations costs/MT: . $4.29
Quantity landfilled, MT: 454
Construction costs, $/MT: $ NA
Leachate collection: . . none
Type of liner: . . . Natural clay
Source of cover: . . . . on-site

This is an example of one part of a regional solid waste management system. The transfer station studied is operated by one of 17 municipalities which are served by a county landfill.

The City operates the haul, transfer station and transfer in large vehicles components of the system. Haul is conducted in relatively small collection trucks. The waste is collected at the transfer station where it is packed into a $60m^3$ vehicle and transfered to the county owned landfill.

The landfill is a trench and fill type, designed with two 18 ft. (5.5 m) lifts. Because of very tight natural soils, there is no leachate collection system.

CASE # 15

Type: . . . . . Shredder
State: . . . . . Wisconsin

Labor Rate/hr: $5.62
Annual rainfall,cm: . . . 83

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 27
Processed, MT/day: . . . 181
Cost/MT: $8.57
Average particle size, cm 8

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . .
MT/load: 18
distance, km: . . . 3.2
Cost/MT: $1.72
Vehicle: . . 18 ton open-back

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 10
Operations costs/MT: . $ NA
Quantity landfilled, MT: 588
Construction costs, $/MT: $ NA
leachate collection: . . To sewer
Type of liner: . . . Natural clay
Source of cover: . . . . on-site

The key points of interest in this solid waste management facility are the county owned and operated shredder and landfill. The haul component of the system is performed by a large number of municipal and private hualers serving the 20 communities in the county.

The shredding facility was origially built to produce RDF for area industries and is equipped with a ferrous removal. Approximately two thirds of the wastes are shredded, while the remainder is landfilled directly. The shredder is well operated and maintained.

An aggressive source separation program has greatly reduced the amount of unacceptable wastes being delivered to the shredder. Wastes which are difficult to shred must be taken directly to the landfill, at a higher tipping charge than shreddable wastes. Violaters find that they are not permitted to take any wastes to the shredder and thus face increased costs.

The wastes are transfered in large vehicles to the landfill located a few miles away. The landfill is operated by the county highway department and there are no accurate records of manpower and equipment assigned to this task. The facility is an area type fill partially below ground and partially above ground with a leachate collection system.

CASE # 16

Type: . . . . . Direct Haul
State: . . . . . Pennsylvania

Labor Rate/hr: $5.15
Annual rainfall,cm: . . . 85

HAULING (COLLECTION VEHICLES)

Ownership: . . . . Public & Private
Load, MT: . . . . NA
Haul Distance, km 32
Cost/MT: . . . . . $ NA
% of time in Haul NA%

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

Not Applicable

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 78
Operations costs/MT: . $4.41
Quantity landfilled, MT: 63
Construction costs, $/MT: $13.62
leachate collection: . . Aerated Lagoon
Type of liner: . . . . . Clay
Source of cover: . . . . on-site

This is an excellent example of a small rural community solid waste management system. Several communities and a number of private haulers deliver wastes to a county owned landfill.

The landfill is equipped with leachate collection and aerated leachate lagoons. The site is unique in that it is located on National Park Service lands. It is also unique in that over 90 ft. (28 m) of gravel has been excavated in anticipation of establishing a gravel and sand operation to partially offset costs. The facility is supported by tipping fees, since the gravel operation has not yet been successful. Although the facility was started with all new equipment, giving it relatively high capital costs, the salaries are quite low.

CASE # 17

Type:	Direct Haul	Labor Rate/hr:	$4.83
State:	Pennsylvania	Annual rainfall,cm: . . .	108

HAULING (COLLECTION VEHICLES)

Ownership:	Public & Private
Load, MT:	NA
Haul Distance, km	NA
Cost/MT:	
% of time in Haul	%

PROCESSING

Ownership:	
Rated Capacity, MT/hr: .	
Processed, MT/day: . . .	
Cost/MT:	$
Average bale size, MT: .	

TRANSFERING (LARGE VEHICLES)

Ownership:	
MT/load:	
distance, km: . . .	
Cost/MT:	$
Vehicle: .	

LANDFILL

Ownership:	Public
Method:	Area
Fillable area, ht: . . .	6.9
Operations costs/MT: .	$3.79
Quantity landfilled, MT:	63
Construction costs, $/MT:	$12.62
Leachate collection: . .	Aerated Lagoons
Type of liner:	Clay
Source of cover:	on-site

The is a small regional solid waste management system. The system provides a landfill facility for all of the municipalities and unincorporated areas in the county. Several municipalities and private contractors perform the haul component of the system. All vehicles are charged a tipping fee at the landfill.

The landfill, which has leachate collection and aerated leachate lagoons, is supported by the tipping fees. The facility is operated in an area fill manner. This facility made considerable use of second hand equipment to reduce capital costs.

Currently about 40% of the wastes handled at the site come from one city which is considering alternative disposal options, including resource recover. Should the city pull out, it is likely that the tipping fees for the remaining users will go up to cover fixed capital costs.

CASE # 18

Type:	Transfer	Labor Rate/hr:	$5.60-$6.89
State:	California	Annual rainfall,cm: . . .	43

HAULING (COLLECTION VEHICLES)

Ownership:	Public
Load, MT:	5.8
Haul Distance, km .	16
Cost/MT:	$1.73
% of time in Haul .	9%

PROCESSING

Ownership:	Public
Rated Capacity, MT/hr: .	35
Processed, MT/day: . . .	189
Cost/MT:	$2.24

TRANSFERING (LARGE VEHICLES)

Ownership:	Public
MT/load:	14
distance, km: . . .	21
Cost/MT:	$3.81
Vehicle: . .	16 ton open top

LANDFILL

Ownership:	Public
Method:	Canyon fill
Fillable area, ht: . . .	303
Operations costs/MT: .	$1.76
Quantity landfilled, MT:	4,897
Construction costs, $/MT:	$0.09
Leachate collection: . .	on-site treatment
Type of liner:	none
Source of cover:	on-site

This is the largest facility included in this study. The solid waste management system consists of a transfer facility which processes a portion of the wastes, which are delivered to a large regional landfill.

A city operates the haul, transfer station and transfer in large vehicles portions of the system for its residents as a public service. The transfer station is a simple pit type with two tractors.

The county landfill is a relatively unique canyon type fill. Because of the natural topography, there are essentially no excavation costs. In an effort to reduce the seagull problem, fish wire has been strung over the top of the canyon. Because it is such a large facility, separate faces are operated for transfer vehicles, haul vehicles and private vehicles.

CASE # 19

Type:	Direct Haul	Labor Rate/hr:	$5.60
State:	California	Annual rainfall,cm: . . .	43

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Not Applicable

TRANSFERING (LARGE VEHICLES)

Not applicable

LANDFILL

Ownership:	Public
Method:	Canyon Fill
Fillable area, ht: . . .	48
Operations costs/MT: .	$1.95
Quantity landfilled, MT:	907
Construction costs, $/MT:	$0.10
leachate collection: . .	none
Type of liner:	none
Source of cover:	on-site

This is a direct haul landfill solid waste management system. The facility is one of several operated by a large metropolitan county. Waste from a wide variety of sources, residential, industrial, commercial and construction, arrive at the site in a multitude of vehicles, leading to severe congestion problems at the site.

The facility is a canyon type fill with 12-20 ft. (3-5 m) lifts and an anticipated maximum depth of 60 ft. (17 m). There are no stationary facilities at the site and no leachate management facilities. The lack of these facilities combined with the lower cost of canyon fills results in very low landfilling costs for this facility.

CASE # 20

Type: . . . . . Direct Haul
State: . . . . . California

Labor Rate/hr: . . . . $8.50-$8.80
Annual rainfall,cm: . . . 43

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load, MT: 5
Haul Distance, km . 24
Cost/MT: $4.47
% of time in Haul . 21%

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

Not applicable

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Canyon Fill
Fillable area, ht: . . . 1.0
Operations costs/MT: . $3.24
Quantity landfilled, MT: 1189
Construction costs, $/MT: $0.29
leachate collection: . . recycle
Type of liner: . . . . . none
Source of cover: . . . . on-site

This is a municipal solid waste management system consisting of municipal collection trucks and a direct haul landfill. The haul component of the system is operated by the city and is relatively effecient compared to other sites visited. This is probably due, partially, to the large collection trucks used.

The landfill is a canyon type fill with relatively low construction costs. Only municipal trucks are allowed to deliver wastes to the landfill, primarily to alleviate traffic congestion. The facility has a significant fixed capital cost for a scale house and administrative building.

CASE # 21

Type: . . . . . Direct Haul
State: . . . . . California

Labor Rate/hr: $6.43
Annual rainfall,cm: . . . 28

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 110
Operations costs/MT: . $4.03
Quantity landfilled, MT: 2,721
Construction costs, $/MT: $1.59
Leachate collection: . . Recycle
Type of liner: . . . . . None
Source of cover: . . . . on-site

This is one of three landfills serving a large metropolitan area. Municipal collection vehicles and private haulers each contribute about one third of the waste with the remaining third equally divided between private automobiles and construction debris.

The city owns and operates this landfill making extensive use of leased equipment, reducing upfront capital costs and maintenance. Because it is so large specialized equipment, designed for optimal performance of a particular task, can be used to great advantage. The facility is opertaed in a conventionl area fill manner and there is no leachate collection primarily due to the dry climate.

CASE # 22

Type:	Transfer
State:	California
Labor Rate/hr:	$7.98-$8.87
Annual rainfall,cm: . . .	56

HAULING (COLLECTION VEHICLES)

Ownership:	Public
Load, MT:	6
Haul Distance, km .	40
Cost/MT:	$12.47
% of time in Haul .	38%

PROCESSING

Ownership:	Public
Rated Capacity, MT/hr: .	43
Processed, MT/day: . . .	280
Cost/MT:	$5.59

TRANSFERING (LARGE VEHICLES)

Ownership:	Public
MT/load:	18
distance, km: . . .	48
Cost/MT:	$5.57
Vehicle: .	

LANDFILL

Ownership:	Public
Method:	Area
Fillable area, ht: . . .	211
Operations costs/MT: .	$2.12
Quantity landfilled, MT:	1,088
Construction costs, $/MT:	$0.25
Leachate collection: . .	none
Type of liner:	none
Source of cover:	on-site

The solid waste management system for this county incudes two transfer stations and one landfill. The waste is collected in county owned collection vehicles and delivered to one of the two transfer stations. The average haul distance is very long resulting in unusually high haul costs.

Data was collected on the operaton of one of the transfer stations. The facilty operates 365 days per year and has only two days of storage for unprocessed waste. Wastes are compacted into large transfer vehicles. The landfill employs the conventional area fill method.

CASE # 23

Type: . . . . . Direct Haul
State: . . . . . Nevada

Labor Rate/hr: . . . . $6.27-$6.62
Annual rainfall,cm: . . . 26

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Private
Load, MT: 6
Haul Distance, km . 4.8
Cost/MT: $3.55
% of time in Haul: . 19%

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

LANDFILL

Ownership: . . . . . Private
Method: . . . . . Trench & Fill
Fillable area, ht: . . . 40
Operations costs/MT: . $2.15
Quantity landfilled, MT: 206
Construction costs, $/MT: $1.03
Leachate collection: . . none
Type of liner: . . . . . none
Source of cover: . . . . on-site

This privately owned landfill serves a metropolitan area consisting of one city and the surrounding counties. The haul portion of the system is a mixture of some private and public collector. Over 60% of the waste received at the landfill arrives in collection trucks which are owned and operated by the firm which owns the landfill.

The landfill opened in 1972 and has an anticipated closing date of 1990. There have been serious drainage problems at the site. While there is no leachate management system, two monitoring wells have been installed to evaluate the impact of the landfill.

CASE # 24

Type:	Direct Haul	Labor Rate/hr:	$5.30
State:	Massachusetts	Annual rainfall,cm: . . .	101

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

Not applicable

LANDFILL

Ownership:	Public
Method:	Area
Fillable area, ht: . . .	28
Operations costs/MT: .	$6.58
Quantity landfilled, MT:	55
Construction costs, $/MT:	$2.76
leachate collection: . .	none
Type of liner:	none
Source of cover:	on-site

This is an example of a Regional Refuse District. Three communities formed the district for the sole purpose of having a joint landfill. All three communties have their own residential collection systems and there are commercial haulers as well.

The landfill is a conventional area type fill and generates funds from tipping fees charged on all waste. The district has purchased used equipment as a method of keeping costs down.

CASE # 25

Type: . . . . . Baler
State: . . . . . Maine

Labor Rate/hr: . . . . $4.50-$5.00
Annual rainfall,cm: . . . 155

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 45
Processed, MT/day: . . . 230
Cost/MT: $11.88
Average bale size, MT: . 1.2

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . .
MT/load: 1.9
distance, km: . . . 10
Cost/MT: $2.79
Vehicle: . . 36 ton flat bed

LANDFILL

Ownership: . . . . . Private
Method: . . . . . Trench & Fill
Fillable area, ht: . . . 32
Operations costs/MT: . $3.94
Quantity landfilled, MT: 116
Construction costs, $/MT: $1.41
Leachate collection: . . on-site
Type of liner: . . . . . PVC
Source of cover: . . . . on-site

A regional district associated with the regional council of governments owns this solid waste management system. Several public and private parties participate in the haul portion of the system.

The baler is owned and operated by the district. It was built in 1977 and currently operates at about 60% of design capacity. Approximately 10% of the wastes, scrap leather, shells, cloth and rags, bypass the baler. The facility did not ave a single day lost to down time during the year for which data was collected.

A private contractor transfers the bales from the baler to the landfill and shares responsibility for operating the landfill with the district.

CASE # 26

Type: . . . . . Baler
State: . . . . . Alabama

Labor Rate/hr: . . . . $4.20-$6.00
Annual rainfall,cm: . . . 143

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 34
Processed, MT/day: . . . 254
Cost/MT: $5.52
Average bale size, MT: . 1.1

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 23
distance, km: . . . 21
Cost/MT: $2.46
Vehicle: . . 25 ton flat bed

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 56
Operations costs/MT: . $1.21
Quantity landfilled, MT: 250
Construction costs, $/MT: $0.49
leachate collection: . . none
Type of liner: . . . . . none
Source of cover: . . . . on-site

This is a muncipality owned and operated solid waste management system. Municipal collectors and a private contractor serving the state university are the only haulers.

The baler-transfer station was built in 1978 and currently operates at near design capacity. The facility lost only six days to down time during the year for which data was collected and generally has an excellent operating record. Large flat bed trucks are used to haul the bales to the city owned balefill.

The balefill accepts only baled wastes. Because of poor drainage, two bale cells are worked simultaneously. The smaller cell, near the entrance to the site is used during wet weather when the rest of the balefill is not passable.

CASE # 27

Type:	Baler
State:	Georgia
Labor Rate/hr:	$5.12-$5.77
Annual rainfall,cm: . . .	140

HAULING (COLLECTION VEHICLES)

Ownership:	Public
Load, MT:	7
Haul Distance, km .	10
Cost/MT:	$7.41
% of time in Haul .	25%

PROCESSING

Ownership:	Public
Rated Capacity, MT/hr: .	45
Processed, MT/day: . . .	140
Cost/MT:	$25.76
Average bale size, MT: .	1.5

TRANSFERING (LARGE VEHICLES)

Ownership:	Public
MT/load:	17
distance, km: . . .	5
Cost/MT:	$7.83
Vehicle: . . .	18 ton flat bed

LANDFILL

Ownership:	Public
Method:	Area
Fillable area, ht: . . .	45
Operations costs/MT: .	$2.04
Quantity landfilled, MT:	1,133
Construction costs, $/MT:	$0.26
leachate collection: . .	none
Type of liner:	none
Source of cover:	on-site

This is a large municipal solid waste management system which employs the tied bale technology. The waste is first shredded and then baled with baling wire, similar to hale bales. The primary disadvantage of this approch is the high cost of the baling wire.

Approximately 20% of the city wastes is processed at the baling facility while 80% goes to the three landfills. The baling facility is a converted incinerator. Wastes are shredded and then baled. The system has a design capacity of 45 tons per hour and is currently handling about 140 tpd.

The landfill for which data was collected receives all of the baled waste as well as a portion of the unbaled waste from the city. There are two different access roads and operating faces for the baled and unbaled waste:

CASE # 28

Type: . . . . . Transfer
State: . . . . . Florida

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load, MT: 5
Haul Distance, km . 7
Cost/MT: $3.47
% of time in Haul . 19%

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 18
distance, km: . . . 22
Cost/MT: $1.58
Vehicle: . . 36 ton open back

Labor Rate/hr: . . . . $4.25-$7.28
Annual rainfall,cm: . . . 202

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 17
Processed, MT/day: . . . 117
Cost/MT: $5.15

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Trench & Fill
Fillable area, ht: . . . 32
Operations costs/MT: . $5.57
Quantity landfilled, MT: 508
Construction costs, $/MT: $1.79
leachate collection: . . none
Type of liner: . . . natural clay
Source of cover: . . . . on-site

This solid waste management system consists of city-owned transfer station and a county owned landfill. Wastes are brought to the transfer sttaion primarily by municipal collection trucks. The transfer station has two stationary compactors and operates four large transfer vehicles.

The wastes from this transfer facility constitute about 20% of the wastes received at the county owned landfill. This landfill has experienced considerable drainage problems.

CASE # 29

Type:	Baler
State:	Georgia

HAULING (COLLECTION VEHICLES)

Insufficient data

TRANSFERING (LARGE VEHICLES)

Ownership:	Public
MT/load:	18
distance, km: . . .	29
Cost/MT:	$1.76
Vehicle: . .	33 ton flat bed

Labor Rate/hr:	$4.00-$4.80
Annual rainfall,cm: . . .	151

PROCESSING

Ownership:	Public
Rated Capacity, MT/hr: .	60
Processed, MT/day: . . .	453
Cost/MT:	$6.00
Average bale size, MT: .	1.2

LANDFILL

Ownership:	Public
Method:	Trench & Fill
Fillable area, ht: . . .	45
Operations costs/MT: .	$1.54
Quantity landfilled, MT:	635
Construction costs, $/MT:	$0.17
leachate collection: . .	none
Type of liner:	gravel
Source of cover:	on-site

This is a county owned solid waste management facility which includes one baler, a balefill and a conventional landfill. The baling facility accepts wastes from all over the county. It was built in 1973 and lost only 10 days to down time during the year for which data was collected.

The county built a new balefill especially to receive waste from the processing facility. All waste which bypasses the balefill is directed to the other landfill.

CASE # 30

Type: . . . . . Baler
State: . . . . . Nebraska

Labor Rate/hr: . . . . $7.04-$7.75
Annual rainfall,cm: . . . 72

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 45
Processed, MT/day: . . . 296
Cost/MT: $13.13
Average bale size, MT: . 1.4

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 34
distance, km: . . . 5
Cost/MT: . . . . $
Vehicle: . . 40 ton rail cars

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 18
Operations costs/MT: . $1.72
Quantity landfilled, MT: 308
Construction costs, $/MT: $ NA
Leachate collection: . . Discharge to sewer
Type of liner: . . . . . clay
Source of cover: . . . . on-site

This is a unique solid waste management system. The waste is processed into either tied or untied bales and then transported by railway car to a balefill. The bales are transferred onto wooden pallets and transferred by forklift to the rail flatcars. A single train per day is hauled to the landfill site on a per car contract with the railroad.

CASE # 31

Type: . . . . . Direct Haul
State: . . . . . Kansas

Labor Rate/hr: . . . . $5.58-$6.31
Annual rainfall,cm: . . . 96

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load, MT: 5
Haul Distance, km . 16
Cost/MT: $6.24
% of time in Haul . 21%

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

Not applicable

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 53
Operations costs/MT: . $2.30
Quantity landfilled, MT: 330
Construction costs, $/MT: $1.79
Leachate collection: . . none
Type of liner: . . . . . none
Source of cover: . . . . on-site

This county run regional landfill receives wastes from over 17 communities. The county operates its own direct haul fleet.

The most unique aspect of this system is the use of old Air Force facilities at a very low cost.

CASE # 32

Type: . . . . . Direct Haul
State: . . . . . Kansas

Labor Rate/hr: . . . . $5.28-$5.52
Annual rainfall,cm: . . . 100

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load, MT: 7
Haul Distance, km . 10
Cost/MT: $9.98
% of time in Haul . 23%

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 23
Operations costs/MT: . $3.31
Quantity landfilled, MT: 82
Construction costs, $/MT: $2.00
leachate collection: . . none
Type of liner: . . . . . none
Source of cover: . . . . on-site

This is a region solid waste management system. The City operates a fleet of haul vehicles while most of the county is served by private haulers.

The landfill, which is owned and operated by the city, receives waste only from direct haul vehicles and private residents. The facility also serves a seaonsal military installation, resulting in considerable variation in the quantities of waste landfilled.

CASE # 33

Type: . . . . . Transfer
State: . . . . . Pennsylvania

Labor Rate/hr: . . . . $5.61-$6.40
Annual rainfall,cm: . . . 135

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 34
Processed, MT/day: . . . 132
Cost/MT: $2.47

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 14.5
distance, km: . . . 18
Cost/MT: . . . . $NA
Vehicle: . . 14 ton open-back

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 10
Operations costs/MT: . $ NA
Quantity landfilled, MT: 304
Construction costs, $/MT: $ NA
Leachate collection: . . areation-recycle
Type of liner: . . PVC-single layer
Source of cover: . . . . on-site

The county owns and operates a transfer station and a regional landfill. 30% of the landfill's volume comes from the transfer station, the rest from a variety of jursidictions in direct haul vehicles. All of the municipal waste is picked up by private haulers and brought to the transfer station. The haul from transfer station to landfill is 11 miles one way and is handled by a private contractor.

CASE # 34

Type: . . . . . Transfer
State: . . . . . Pennsylvania

Labor Rate/hr: . . . . $5.25-$8.23
Annual rainfall,cm: . . . 135

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 68
Processed, MT/day: . . . 269
Cost/MT: . . . . . $ NA (1.99)

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 14
distance, km: . . . 24
Cost/MT: . . . . $ NA
Vehicle: . . 60 ton open back

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Ravine
Fillable area, ht: . . . 3.2
Operations costs/MT: . $ NA (1.15)
Quantity landfilled, MT: 907
Construction costs, $/MT: $ NA (2.94)
leachate collection: . . recycle
Type of liner: . . . . . clay
Source of cover: . . . . off-site

This county owns and operates a transfer station and operates a landfill in a leased quarry. The transfer station serves 11 municipalities in the southeastern part of the county. The landfill also receives waste from several large private haulers and several other municipal operations. Haul distance from transfer station to landfill is 15 miles (24 km) one way.

CASE # 35

Type: . . . . . Shredder
State: . . . . . Delaware

Labor Rate/hr: $6.58
Annual rainfall,cm: . . . 130

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Private
Rated Capacity, MT/hr: . 127
Processed, MT/day: . . . 1,000
Cost/MT: . . . . . $ NA
Average particle size,cm 5

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Private
MT/load: 8
distance, km: . . . 0.5
Cost/MT: . . . . $ NA
Vehicle: . . flat-bed

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 55
Operations costs/MT: . $ NA
Quantity landfilled, MT: 1,270
Construction costs, $/MT: $ NA
Leachate collection: . . discharge to sewer
Type of liner: . . . . . none
Source of cover: . . . . off-site

The county operates a landfill with an on-site shredding operation and off-the-road transfer in custom-built trailers. The shredder was designed and built and is operated under contract by a private firm. About half the refuse that comes to the landfill is shredded and ferrous scrap is recovered, although at present they are just stockpiling.

CASE # 36

Type:	Transfer
State:	Washington
Labor Rate/hr:	$7.85-$10.62
Annual rainfall,cm: . . .	86

HAULING (COLLECTION VEHICLES)

Ownership:	Public
Load, MT:	4
Haul Distance, km .	11
Cost/MT:	$2.95
% of time in Haul .	24%

PROCESSING

Ownership:	Public
Rated Capacity, MT/hr: .	17
Processed, MT/day: . . .	328
Cost/MT:	$1.63

TRANSFERING (LARGE VEHICLES)

Ownership:	Public
MT/load:	15
distance, km: . . .	19
Cost/MT:	$2.44
Vehicle: .	

LANDFILL

Ownership:	Public
Method:	Area
Fillable area, ht: . . .	23
Operations costs/MT: .	$ NA
Quantity landfilled, MT:	NA (445)
Construction costs, $/MT:	$ NA
Leachate collection: . .	Discharge to sewer
Type of liner:	none
Source of cover:	on-site

This facility is one of two county owned and operated transfer facilities. It was built in 1975 on the site of an old municipal landfill at a cost of $360,000. The facility requried major repair work in 1979 because the ground underneath the station settled causing the floor to crack. It handles an average of 328 tons in the 18 hours it is open each day. This is only 60% of the capacity. Traffic congestion into the facility limits the amount of waste handled -- on weekends users can face hour long lines.

The wastes are taken by tractor trailer to a county owned non-conforming landfill site 12 miles (19 km) distant. A new fully conforming landfill was scheduled to start operating soon after this tudy was completed and all wastes will be trucked the 16 miles to that site. The new site is fully lined and has a complete leachate treatment system. The county expects it will last 8 years. All of the equipment used at both the transfer facility and landfill was purchased new. Construction of the landfill was contracted out on a cost plus fixed fee contract. The total cost was $5,700,000.

CASE # 37

Type: . . . . . Baler
State: . . . . . Washington

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load, MT: 6
Haul Distance, km . 32
Cost/MT: $4.93
% of time in Haul . 25%

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 4
distance, km: . . . 0.3
Cost/MT: $0.29
Vehicle: . . 4 ton open back truck

Labor Rate/hr: . . . . $6.22-$7.22
Annual rainfall,cm: . . . 45

PROCESSING

Ownership: . . . . . .
Rated Capacity, MT/hr: . 14
Processed, MT/day: . . . 47
Cost/MT: $10.67
Average bale size, MT: . 0.9

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Trench & Fill
Fillable area, ht: . . . 24
Operations costs/MT: . $4.13
Quantity landfilled, MT: 60
Construction costs, $/MT: $ NA
leachate collection: . . none
Type of liner: . . . . . none
Source of cover: . . . . on-site

The county operates both a baler and landfill adjacent to one another. The baler, built in 1975 at a cost of $97,000 handles approximately 47 tons/day, six days/week. There has been virtually no down time at the facility since it was opened. Major changes were made in 1978. The county replaced the conveyor with a more powerful one at a cost of $83,400 and added a set of scales costing $53,,000. The bales weigh approximately 0.9 tons and are almost 3 cubic yards (2.4 m^3) in volume. These are transferred on a small 4x4 army truck to the landfill site 1/4-mile (400 m) distant. The landfill contains 60 fillable acres (24 ht) and was opened at the same time as the baler. It is expected to last for an additional 30 years. This is 10 years longer than original estimates because the county instituted a self-supporting recycling program for cardboard, aluminum, and glass. The landfill has no liner and cost a total of $167,500 to purchase and construct. Constrution was contracted out. The facilities serve 42,000 people.

CASE # 38

Type: . . . . . Direct Haul
State: . . . . . Washington

Labor Rate/hr: $6.76
Annual rainfall,cm: . . . 18

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Not applicable

TRANSFERING (LARGE VEHICLES)

Not applicable

LANDFILL

Ownership: . . . . . .
Method: . . . . . .
Fillable area, ht: . . . 32
Operations costs/MT: . $4.32
Quantity landfilled, MT: 217
Construction costs, $/MT: $ NA
leachate collection: . .
Type of liner: . .
Source of cover: . . . .

The landfill is a county run facility serving 80,000 of the 150,000 residents. Opened in 1974, it handles approximately 217 tons/day, seven days a week, and was originally expected to last only until the early 1980s. By digging the site deeper, increasing the slope, and purchasing another canyon, the 80 acre (32 ht) site is now expected to last until the early 1990s. The total cost of construction was $376,500 spread over the last five years. A major portion of this, and one major operating expense was digging the well, along with operating the pump necessary to bring water for irrigation and landfill operators up the 400 ft. (125 m) from groundwater level. Together, the well and pump cost $134,300.

Except for one bulldozer which was 2 years old when the county acquired it, all equipment used at the facility was purchased new. The only major expenditure occured when the county hired a contractor for $40,000 to prepare the new canyon for landfilling.

CASE # 39

Type:	Baler
State:	Washington

HAULING (COLLECTION VEHICLES)

Ownership:	Private
Load, MT:	3
Haul Distance, km .	15
Cost/MT:	$1.73
% of time in Haul .	6%

TRANSFERING (LARGE VEHICLES)

Ownership:	Private
MT/load:	18
distance, km: . . .	19
Cost/MT:	$3.59
Vehicle: . .	flat-bed

Labor Rate/hr:	$6.50-$8.30
Annual rainfall,cm: . . .	20

PROCESSING

Ownership:	Private
Rated Capacity, MT/hr: .	23
Processed, MT/day: . . .	18
Cost/MT:	$24.82
Average bale size, MT: .	0.9

LANDFILL

Ownership:	Private
Method:	Area
Fillable area, ht: . . .	40
Operations costs/MT: .	$3.72
Quantity landfilled, MT:	227
Construction costs, $/MT:	$ NA
leachate collection: . .	none
Type of liner:	none
Source of cover:	on-site

This site consists of a privately owned and operated baler and landfill site. Although the two facilities are owned by the same company, which also provides a collection service, the two sites are some 12 miles apart. The baling facility was built in 1974 at a cost of $500,000. The average daily load of 18 tons takes only a couple of hours to bale. The faciltiy serves as a recycling center for metals and cardboard, glass and newsprint. The baled wastes are transferred the 12 miles (19 km) to the landfill 3 days a week in a tractor trailer.

The landfill was originally opened in 1955 and converted to a sanitary site in 1970. It should last for another 10-15 years. There is only weekly cover, no liner leachate treatment or other controls.

All equipment was purchased new except for the container truck used for hauling which was 5 years old when purchased in 1977. The site serves 60,000.

CASE # 40

Type: . . . . . Transfer
State: . . . . . Colorado

Labor Rate/hr: . . . . $6.81-$7.33
Annual rainfall,cm: . . . 43

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 5.4
Processed, MT/day: . . . 26
Cost/MT: $6.26

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 13
distance, km: . . . 27
Cost/MT: $5.98
Vehicle: .

LANDFILL

Ownership: . . . . . Public
Method: . . . . . .
Fillable area, ht: . . . 6
Operations costs/MT: . $3.19
Quantity landfilled, MT: 470
Construction costs, $/MT: $
Leachate collection: . .
Type of liner: . .
Source of cover: . . . .

This solid waste management system is owned and operated by a county. A small transfer station was built in 1974 for the convenience of an outlying community. Located on a former landfill site the transfer station consists of a self-compacting trailer and a small office. Waste from the transfer station constituted less than 3% of the waste handled at the landfill.

The landfill has been in operation for over 80 years. It was scheduled for closure four years prior to this study. An additional 10 feet (3 m) left provide additional capacity. The landfill is now substantially above grade, resulting in sever problems with blowing refuse.

CASE # 41

Type: . . . . . Baler
State: . . . . . Wyoming

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load/MT: 1.5
Haul Distance, km . 6
Cost/MT: $6.61
% of time in Haul . 13%

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 12
distance, km: . . . 1
Cost/MT: $3/31
Vehicle: . . 2 ton open back

Labor Rate/hr: . . . . $3.80-$4.10
Annual rainfall,cm: . . . 31

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 12
Processed, MT/day: . . . 12
Cost/MT: $28.74
Average bale size, MT: . 0.9

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Trench & Fill
Fillable area, ht: . . . 30
Operations costs/MT: . $13.76
Quantity landfilled, MT: NA
Construction costs, $/MT: $ NA
Leachate collection: . . none
Type of liner: . . . . . clay
Source of cover: . . . . off-site

The city provides collection, baling and landfilling services. The baler, built in 1975 at a cost of $322,000 processes an average of 12 tons/day, five days/week. A forklift is used to carry the bales to the landfill located one-half-mile away. The present landfill was opened in 1975 on land that is owned by the town and was used as an open burning dump for many years.

The landfill is constructed in phases. Each year the town contracts to have another portion prepared to recieve wastes. Last year this cost $12,000. The landfill is operated in an area method with three bale-high lifts. All cover must be purchased.

CASE # 42

Type:	Baler
State:	Nebraska
Labor Rate/hr:	$4.05-$4.42
Annual rainfall,cm: . . .	41

HAULING (COLLECTION VEHICLES)

Ownership:	Public
Load, MT:	2
Haul Distance, km .	2
Cost/MT:	$0.72
% of time in Haul .	6%

PROCESSING

Ownership:	Public
Rated Capacity, MT/hr: .	27
Processed, MT/day: . . .	13
Cost/MT:	$12.84
Average bale size, MT: .	9

TRANSFERING (LARGE VEHICLES)

Ownership:	Public
MT/load:	2
distance, km: . . .	0.2
Cost/MT:	$1.42
Vehicle: . .	2 ton flat bed

LANDFILL

Ownership:	Public
Method:	Area
Fillable area, ht: . . .	78
Operations costs/MT: .	$7.85
Quantity landfilled, MT:	14
Construction costs, $/MT:	$ NA
leachate collection: . .	none
Type of liner:	none
Source of cover:	off-site

The city runs a collecton, baling and landfilling operation that serves a population of 1,000 with a staff of five. In mid 1979, the community switched from a conventional to a fully automated collection system requiring only a one man crew. The baler was built in 1975 at a cost of $182,604. It processes approximately 13 tons/day, 5 days/week. A fork lift carries the bales the 1/4-mile (.4 km) to the landfill. All of the equipment used by the town has been purchased new.

Construction debris, tires, waste wood, and metals are stored for recycling. To date, there has only been a limited market for these materials, however.

The landfill, which was expected to last until 2023, was built in 1975 at a total cost of $30,000. The balefill consists of an area fill with three bale lifts. There is no daily cover.

CASE # 43

Type: . . . . . Baler
State: . . . . . New York

HAULING (COLLECTION VEHICLES)

Ownership: . . . . . Public
Load, MT: 6
Haul Distance, km . 10
Cost/MT: $10.75
% of time of Haul . 29%

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 27
distance, km: . . . 0.8
Cost/MT: $9.29
Vehicle: . . 47 ton flat-bed

Labor Rate/hr: . . . . $6.75-$7.25
Annual rainfall,cm: . . . 150

PROCESSING

Ownership: . . . . . Public
Rated Haul ity, MT/hr: . 120
Processed, MT/day: . . . 12
Cost/MT: . . . . . $ NA
Average bale size, MT: . 1.3

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 46
Operations costs/MT: . $2.28
Quantity landfilled, MT: 548
Construction costs, $/MT: $1.84
leachate collection: . .
Type of liner: . .
Source of cover: . . . .

Solid waste services for this town consist of municipal and private collection; and municipal operation of a baler, two incinerators, and a landfill. In 1979, the town collected an estimated 118,000 tons, and processed and disposed of over 227,000 tons of solid waste.

Municpal collection is from residences using 20-cubic yard (16 m^3) packers. This refuse, together with that from rivate haulers is taken to a facility that includes all processing and disposal activitieis. The baler was brought into operation in 1977. Although designed to process 1080 tons per day, maintenance problems have continually hampered operations. In 1979, only 4,856 tons were baled. The landfill, with a natural clay liner, is currently operating in the first several phases that will extend its useful life well beyond the original intended closing date.

CASE # 44

Type: . . . . . Transfer
State: . . . . . New York

Labor Rate/hr: . . . . $6.26-$9.33
Annual rainfall,cm: . . . 150

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . NA
Processed, MT/day: . . . NA
Cost/MT: . . . . . $ NA

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 7
distance, km: . . . 24
Cost/MT: . . . . $4.45-$6.47
Vehicle: . . 35 ton flat-bed

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Above ground
Fillable area, ht: . . . 34
Operations costs/MT: . $2.41
Quantity landfilled, MT: 1,395
Construction costs, $/MT: $1.03
leachate collection: . . on-site lagoons
Type of liner: . . PVC double, liner
Source of cover: . . . . on-site

This solid waste management system consist of municipal transfer station, and landfill. In 1979, the town landfilled an estimated 376,190 tons of solid waste.

A transfer station is located about 15 miles (24 km) from the landfill complex. Individuals bring waste for transfer, and roughly 7 percent of the total waste comes through this station. At the landfill site, there are separate entrances for individuals and refuse collection vehicles, or other trucks capable of unloading directly at the working face. Individuals dispose in containers which are then hauled by off-the-road vehicles. The landfill itself is a highly innovative design -- intended to form a ski mountain which will be 265 feet (82 m) above grade when completed. The base of the fill is lined, with leachate collection. Construction of the base has been phased in three stages. Leachates treatment, consisting of an aerated lagoon, will be operational in the spring of 1981. The town may be required to double-line the final phase of the fill. The current projected closing date is 1988.

CASE # 45

Type: . . . . . Baler
State: . . . . . New York

Labor Rate/hr: . . . . $5.02-$6.41
Annual rainfall,cm: . . . 150

HAULING (COLLECTION VEHICLES)

Insufficient data

PROCESSING

Ownership: . . . . . Public
Rated Capacity, MT/hr: . 112
Processed, MT/day: . . . 199
Cost/MT: $26.91
Average bale size, MT: . 1.5

TRANSFERING (LARGE VEHICLES)

Ownership: . . . . . Public
MT/load: 22
distance, km: . . . 2
Cost/MT: $2.34
Vehicle: . . 25 ton flat-bed

LANDFILL

Ownership: . . . . . Public
Method: . . . . . Area
Fillable area, ht: . . . 30
Operations costs/MT: . $3.45
Quantity landfilled, MT: 315
Construction costs, $/MT: $3.82
Leachate collection: . . Discharge to sewer
Type of liner: . . . . . clay
Source of cover: . . . . on-site

Solid waste services consist of municipal operation of a baler and landfill. In 1979, the town processed an estimated 55,500 tons, and landfilled over 91,000 tons.

The baler and landfill are both located on an 86 acre (35 ht) site. About 60 percent of the incoming wastes are baled. The baler, brought into operation in 1976, is an American Hoist unit manufactured by Harris Press and Shear. The unit is designed to process 910 tons per day if operated or three shifts. In 1979, there were only 20 hours of down time -- an extraordinary performance statistic, based on single-sift operation. Density of bales produced was approximately 1.21 tons/m^3. Baled or raw refuse is landfilled on-site in a double lined landfill. The fill has been excavated to nearly 90 feet (28 m) below grade: this has been done by private contractors, who have paid for the sand removed. There is leachate collection beneath each of the two liners. Currently, leachate is removed and disposed of at a regional wastewater treatment facility. In the past, recycling of the leachate has also been used to stabilize the quality, and to diminish the volume through evaporation. Currently, the landfill has a projected life of 46 years.

In summary, this is a fairly straightforward system of processing and disposal, which is performing quite well. The town has taken relatively innovative steps -- and this, combined with good circumstances and possibly luck, has resulted in fairly effective operations.

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